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ABSTRACT

This report documents research and development performed under the sponsorship of the Cognitive and Neural Sciences Division of the Office of Naval Research in fiscal year 1991. It provides abstracts (title, principal investigator, project code, objective, approach, progress, and related reports) of projects of three program divisions (cognitive science, perceptual science, and biological intelligence). Cognitive science research programs provide a theoretical understanding of the human learner and performer of complex cognitive skills. They address formal cognitive architectures and neurocognitive science; knowledge, skill, and expertise; learning and instruction; and model-based measurement. Perceptual science research programs emphasize perceptual computation and representation in terms of vision, audition, touch, and manipulation. Related topics include haptics and sensory guided motor control and human factors technology. Biological intelligence research programs strive to elucidate the organization, structural bases, and operational algorithms characterizing information processing networks within neural systems. Related topics include computation in large neural networks, single-neuron computation, chemical modulators of information processing, neural processing of sensory information, and computation in olfactory systems. Programs on manpower, personnel, and training research and development; a university research initiative; and stress and performance are also included. (SLD)

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FOREWORD

This booklet describes research carried out under sponsorship of the Cognitive and Neural Sciences Division of the Office of Naval Research (ONR) during fiscal year 1991. The Division's research is organized in three programs: Cognitive Science, Perceptual Science and Biological Intelligence. Each program is described by an overview which is followed by thematic clusters of related efforts. Each cluster is described by individual projects which were active during 1991.

This is one of several means by which we communicate and coordinate our efforts with other members of the research-sponsoring and research-performing communities. We encourage your comments about any feature of this booklet or about the programs themselves. If you wish further information, please do not hesitate to contact members of the staff listed in the Introduction. We welcome your interest in our programs and hope that you will continue to keep us informed of related research efforts.

W. S. VAUGHAN, JR.

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INTRODUCTION

Cognitive and Neural Sciences Division programs are carried out under contracts and grants awarded on the basis of proposals received in response to a Broad Agency Announcement in the Commerce Business Daily. Proposals are evaluated on the scientific merit of the proposed research, the facilities available for its conduct, the competence of the principal investigators, and relevance to Navy needs. The elements that shape our research program are scientific gaps and opportunities, and operational needs identified in Navy planning documents. Our overall aim is to support quality science for the good of the Navy and the nation.

Cognitive and Neural Sciences programs develop fundamental knowledge about human capabilities and performance characteristics which guide Navy and Marine Corps efforts to improve personnel assessments for selection and classification, training, equipment and system designs for human operation and maintenance. One goal is to provide scientific underpinning for more accurate prediction and enhancement of human performance in training and operational environments. A second goal is to understand the neurobiological constraints and computational capabilities of neural information processing systems as guides to design of future teleoperated and robotic systems. The Division has core programs in cognitive, perceptual and neural sciences which seek to understand human behavior at successively deeper levels of analysis. In addition, several Accelerated Research Initiatives (ARI) are underway which complement and extend research topics of interest to the core programs.

Most of the programs are basic in nature, with a selected augmentation of exploratory development effort. This mix of basic and applied research is developed and managed by the Division staff with the able assistance of the other ONR scientists and with helpful guidance and advice from representatives of various Navy and Marine Corps activities. The programs seek to involve innovative civilian scientists in areas of research relevant to Navy and Marine Corps interests, and by so doing provide new perspectives, new insights, and new approaches to naval manpower, personnel, training, equipment and system design problems. This arrangement provides channels for information to flow back and forth between the civilian research community and the naval community, each keeping the other abreast of new developments. The emphasis is on the creation and exploitation of a cumulative scientific knowledge base upon which new technologies can be developed to improve effectiveness of Navy and Marine Corps men and women.

Continuous efforts are made to coordinate the Division's research program with other ONR Divisions, with in-house Navy Laboratories and Centers, and with the research sponsored by other services and other agencies. We work closely with Technology Area Managers in the Office of Naval Technology (ONT), and with their Block Managers in Navy Laboratories and Centers to facilitate transitions from basic to applied research.

The Cognitive and Neural Sciences Division is part of the Life Sciences Directorate, which also includes the Biological Sciences Division. Dr. Steven F. Zornetzer is Director of the Life Sciences Directorate, and Captain James C. Coolbaugh is the Deputy Director for Life Sciences.

DIVISION STAFF

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COGNITIVE SCIENCE

The Cognitive Science research program aims to provide a theoretical understanding of the human learner and performer of complex cognitive skills. This general goal unfolds into several interrelated more specific objectives. First, to provide a theory of the fundamental characteristics of the learner and performer as an information processing system, including a theory of the basis of individual differences in cognitive abilities. Second, to provide a theory of the nature of acquired knowledge and skill involved in performing complex problem-solving and decision-making tasks. Third, to provide a cognitive learning theory that can account for the way in which such complex, structured bodies of knowledge and skill are acquired. Fourth, to provide a precise theory of instruction, founded on cognitive theory, to be used to guide effective education and training of complex cognitive skills. Finally, this research program aims to provide theoretical foundations for personnel testing and assessment. Research in Cognitive Science is expected to lead to the design of efficient instructional systems across a range of content domains of interest to Navy and Marine Corps training programs, to the development of efficient and accurate computer-based personnel assessment systems, and to the design of expert advisory systems compatible with human intellectual characteristics.

The Human Learner: Cognitive Architectures and Neuro-Cognitive Science

Research aimed at discovering and characterizing the stable features of the human learner, emphasizing the later stages of information processing -- cognition rather than perception. Current priorities emphasize neuro-cognitive science, the use of neural evidence to constrain theories of human cognitive architecture. The continued development of those formal theories, which specify information storage capabilities, fundamental cognitive operations and learning mechanisms, remains a major priority. Theories of cognitive architecture provide a deeper and more theoretical account of human abilities. They will provide a sounder foundation for personnel testing and selection, for the adaptation of instructional treatments to individual capabilities, and for the engineering of effective interaction between humans and the artificial systems that are increasingly prevalent in the modern Navy.

Knowledge, Skill and Expertise

Research on knowledge and expertise aims at formal theories of complex human skill. The program emphasizes the expression of theories in the formal languages provided by mathematics and computer science and includes empirical tests of developed models. Projects target a wide range of complex skills, emphasizing problem solving and decision making, so that a general theory can evolve. Research results are intended to provide a general model for skill analysis that can be used to design appropriate training or expert advisory systems.

Learning and Instruction

Research on Learning and Instruction aims to produce a knowledge-rich theory of learning that integrates results of work in the prior clusters and develops a coordinated instructional theory that explains how to produce change -- learning -- in desired directions. Under the Knowledge Acquisition ARI, there is currently a major emphasis on AI-based models of complex human learning. Artificially intelligent, computer-assisted instructional systems as well as more conventional instructional settings are the application areas for the program. In addition, projects are supported which involve either fundamental advances in AI bases for intelligent tutoring or the use of intelligent tutoring systems as a laboratory for investigation into general issues of learning and instruction. Insights into effective learning mechanisms for adaptive artificial systems are also expected to result from this research.

Model-based Measurement

Research in this cluster is developing a technology for constructing verifiable empirically-based models of eminent aspects of performance which lead to robust item-level predictions on complex cognitive tasks. For domains for which cognitive science provides detailed qualitative explanations of performance in terms of well-defined mental structures and processes, research is developing a technology for linking task performance to a taxonomy of those structures and processes. This research provides the technology base for improvements to the testing components which constitute the heart of Navy and Marine Corps personnel and training systems in which case-by-case decisions are made. This includes systems for personnel selection and classification, for career counselling, for the design/selection of instructional interventions, for performance aiding, for certification and for performance evaluation. As the Navy modernizes those systems to take advantage of potential improvements in a computer-based workplace, this research is providing the wherewithal for fundamental improvements to those systems through fundamental improvements to their measurement components.

PERCEPTUAL SCIENCE

Research in the Perceptual Science program emphasizes issues of perceptual computation and representation in the domains of vision, audition, touch and manipulation, multimodal integration, and the control of motor activity. Research results are expected to transition to Navy and Marine Corps systems in the form of enhanced technologies for human factors engineering, machine vision, acoustic signal classification, adaptive filtering, and dexterous manipulators for autonomous and teleoperated vehicles.

Vision and Visual Attention

Vision is viewed as a computational process and projects in this cluster emphasize interdisciplinary approaches. Mathematical models are constrained by neurophysiological evidence and tested by psychophysical experiments. Focus is on modeling early, intermediate, and late-visual processes that construct and recognize visual forms and integrate these forms into complex visual representations. A second thrust inquires into the nature of neural mechanisms of attentional control. In their more evolved forms, visual systems contain special modulatory mechanisms that enable them to adjust quickly and adaptively to momentary fluctuations in environmental demand. These are the neural control mechanisms underlying attention and arousal. Interest within this cluster is on empirical research in human visual performance, neuroanatomy, neurophysiology, and neuropsychology aimed at investigation of the control structures and circuitries underlying visual attention, and the neurochemical modulators governing attentional processing.

Audition

In audition, research projects examine the processing of steady state, transient, and reflected acoustic signals, and model the concurrent processing of complex sound properties and interactions. Current emphasis is on understanding and modeling the classification processes of human listeners, augmented by neurophysiological evidence from other biological species with interesting auditory capabilities and the signal processing capabilities of artificial neural nets.

Haptics and Sensory-Guided Motor Control

In sensory-guided motor control, emphasis is on experimental and theoretical studies of the fundamental issues of coordinated motor function, including the computational bases of force control, and the timing and sequencing of action. Special emphasis is given to work investigating the processes through which sensory information functions as an adaptive guide to coordinated action. Interdisciplinary research is encouraged in psychology, neuroscience, and computer science to achieve an understanding of sensory-guided motor control that will contribute toward enhancement of action adaptability within robotic

systems.

The processing of tactile and kinesthetic information in object recognition is a related area of interest in this cluster. Priority research issues include the identification of perceptual primitives, neural network models for tactile processing in somatosensory centers, and perceptual mechanisms that mediate inferential judgments about object properties, classifications and functions. Interdisciplinary research is encouraged in psychology, neurophysiology and computer science with the goal of understanding the haptic system in order to provide future robotic devices with intelligent hands.

Human Factors Technology

The work described in this cluster constitutes an Exploratory Development project which is designed to extend the basic research program in Perceptual Science toward applications in Naval systems. Currently the project consists of applied research in three topic areas: decision making in command and control systems; teleoperated and robotic systems; and acoustic signal analysis. Current work in the command and control area investigates information processing and decision-making in Naval mission planning, airborne ASW, and sonar signal analysis. Work in teleoperation and robotics seeks to develop the conceptual and technical bases for extending human-like sentience and dexterity into previously unattainable and hazardous underwater environments. Work on acoustic signal analysis aims to develop improved techniques for the detection, localization, and classification of active and passive sonar signals.

BIOLOGICAL INTELLIGENCE

Biological Intelligence programs foster research to elucidate the organization, structural bases, and operational algorithms characterizing information processing networks within neural systems. The goal is to uncover neural architectures and algorithms that can profitably be emulated technologically to yield artificial information processing capabilities of kinds now unique to biological systems. These neural architectures may be derived from either sensory-, motoric- or cognitively-related structures. Overall, the program of research seeks to uncover the organizational principles and operational rules exploited within neural networks to compute intelligent functions, and to emulate these network characteristics within electronic information processing systems.

Computation in Large Neural Networks

This research examines the global dynamics of biological neural networks composed of large numbers of neurons. The goal of this research is a formal description and simulation of the biological computations underlying information processing, learning and cognition in order to design electronic information processing systems with these network characteristics.

Single-Neuron Computation

Real neurons exhibit a much greater computational complexity than the processor elements of most artificial neural networks. Moreover, current neurobiological research shows that adaptive nets can emerge from synaptic modification rules that operate locally, rather than globally. The research in this program would address such issues as the computations performed in neuronal dendritic trees, Hebbian rules, and the neuron as a neuronal network. The goal of this research would be to develop modules, or sub-nets that capture the computational features of real neurons which could form the building blocks for a new generation of neural nets.

Chemical Modulators of Information Processing

A valuable property of biological intelligence is the ability to learn, remember and modify behavior on the basis of experience. Neural plasticity, the ability of neurons to alter the strength of synaptic connections, is the neural basis of learning and memory. This cluster of research explores the mechanisms by which neurochemical modulators and neurotransmitters enable neural plasticity, modify information processing, and alter network dynamics.

Neural Processing of Sensory Information

This research is concerned with the functional organization of sensory neocortex, the computations performed in sensory cortical networks, and the adaptive plasticity of these networks evident at the level of the neuronal receptive

fields. Sensory processing is studied in vision, audition, olfaction, touch and motor control.

Computation in Olfactory Systems

This program is an Accelerated Research Initiative jointly funded by the Biological Sciences and Cognitive and Neural Sciences Divisions. The program aims include a description of the processes involved in olfactory discrimination and classification.

MANPOWER, PERSONNEL AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

This is an interdisciplinary program of exploratory development managed by Dr. Stanley Collyer in the OCNR Office of Naval Technology. Scientific Officers for these projects are located in the Cognitive and Neural Sciences Division and in the Mathematics Division of the Office of Naval Research. Projects which are closely related to the primary emphases of the Cognitive and Neural Sciences Division have been grouped with the related basic research projects, identified by the notation that funds have been provided by ONT Code 222. In this section, there are descriptions of projects addressing unique priorities of the MPT program. This report includes descriptions only for those contracts managed by a Scientific Officer in the Cognitive and Neural Sciences Division.

This program is closely coupled with the operating arms of the Navy and Marine Corps through the mechanism of a planning committee, whose members include ONR Scientific Officers, the Naval Civilian Personnel Command, the Naval Military Personnel Command, the Navy Recruiting Command, the Navy Personnel Research and Development Center, several directorates in the Office of the Chief of Naval Operations, and the Navy Secretariat.

UNIVERSITY RESEARCH INITIATIVE: DECISION MAKING IN HIERARCHICAL TEAMS

This is a special program of basic research developed under the Department of Defense Research Initiation Program within the University Research Initiative. Emphasis is on theory development, variable definition and measurement approaches, modeling and experimentation to deepen our understanding of how coordination is achieved and maintained by hierarchical decision-making teams in stressful environments. This section characterizes the six awards made in FY90 to explore issues in hierarchical team decision making.

A parallel program of exploratory development research was begun by ONT Code 222 during FY90, Tactical Decision Making Under Stress (TADMUS). Mechanisms to insure close coordination between these two programs have been put in place to strengthen transition opportunities.

STRESS AND PERFORMANCE

This program is a core initiative of the Division of Cognitive and Neural Sciences that spans the three CNS programs in Cognitive Science, Perceptual Science, and Biological Intelligence. The primary objective of the program is to relate the physiology of stress to psychological performance. Research supported by the program includes: 1) brain mechanisms of memory that may be differentially affected by stress, 2) individual differences in stress reactivity, 3) predicting individual performance under stress, and 4) modeling team decision-

making under stress. Emphasis is on understanding basic biological and behavioral constituents of the human response to psychological stressors. This program complements the URI-sponsored program: Decisionmaking in hierarchical teams and the TADMUS (Tactical Decision Making Under Stress) program of the Office of Naval Technology.

COGNITIVE SCIENCE

THE HUMAN LEARNER: FORMAL COGNITIVE ARCHITECTURES & NEURO-COGNITIVE SCIENCE

TITLE: Learning and Individual Differences: An Ability/Information-Processing Framework for Skill Acquisition

PRINCIPAL INVESTIGATOR: Phillip L. Ackerman
University of Minnesota
Department of Psychology
(612) 625-9812

R&T PROJECT CODE: 4422543 CONTRACT NO: N0001489J1974

Objective:
The objective is to investigate the relationship between measures of various psychometric abilities and the course of acquisition of skills of various types: perceptual-motor skills, cognitive skills with minimal perceptual-motor components, and fine motor coordination skills.

Approach:
Nine experiments are planned, using appropriately selected skill learning tasks, to examine such questions as the role of cognitive abilities in determining skill transfer, the possibility of changes in measured abilities as a consequence of practice in a skill and the role of various psychometric abilities in determining asymptotic performance. A wide variety of psychometric ability measures will be taken and subjects will undergo prolonged training in order to develop high, asymptotic levels of skill. Tasks studied include variants of a simulated air-traffic control task.

Progress:
Significant progress has been made on the development of the new computerized task environments needed for the research proposed in this grant renewal. One is the second generation Air Traffic Controller task. Voice recognition hardware was evaluated and selected and software development of the voice interface is in progress. The second task, involving acquisition of fine motor skills, has proved more problematic because of the limited availability of both programming/display devices and input devices for 3-D motion.

Report:
Ackerman, P.L. (1990). A correlational analyses of skill specificity: Learning, abilities, and individual differences. Journal of Experimental Psychology: Learning, Memory, and Cognition, **16**, 883-901.

TITLE: Use of Rational Analysis to Design an Architecture for Learning and Problem Solving

PRINCIPAL INVESTIGATOR: John R. Anderson
Carnegie-Mellon University
Department of Psychology
(412) 268-2788

R&T PROJECT CODE: 4422559 CONTRACT NO: N0001490J1489

Objective:
The primary purpose of this grant is to undertake a revision of the ACT* theory of human cognitive architecture, taking into account the implications of a rational analysis of the environmental requirements on human cognition that the PI has already conducted. Empirical studies of problem solving will also be conducted to provide additional constraints on the theory.

Approach:
The lessons arising from a rational analysis of the requirements of a number of theoretically important cognitive tasks will be reflected in a new and improved formulation of the ACT class of computational theories of human cognition. In addition, new empirical problem solving studies will be conducted in order to provide guidance as to how the theory should treat learning in situations in which rules are probabilistic in character, not explicitly taught but induced without instruction, and which involve explicit management of costs and gains.

Progress:
A rational analysis of categorization behavior has been completed and has been shown to account for most of the phenomena of human categorization behavior that have been experimentally observed. A book reporting the previously completed rational analyses has been published. Revision of the ACT* cognitive architecture, taking into account these rational analyses, has begun.

Report:
Anderson, J. R. (1990) The Adaptive Character of Thought, Hillsdale, NJ: Erlbaum.

TITLE: Neural Systems Underlying Visual Recognition in Humans

PRINCIPAL INVESTIGATOR: Antonio R. Damasio
University of Iowa
Behavioral Neurology and Cognitive Neuroscience
(319) 356-4296

R&T PROJECT CODE: 442k002 CONTRACT NO: N0001491J1240

Objective:
The objective is to evaluate competing theories of normal visual cognition and perception by studying patients with focal brain injuries and differential deficits in visual object recognition and naming.

Approach:
Deficits in visual object recognition and naming will be studied in neurological patients with focal cerebral lesions. Subjects will be chosen from a large subject pool on the basis of lesion characteristics. Features of visual stimuli will be varied parametrically to identify and differentiate specific cognitive and perceptual mechanisms underlying behavioral deficits and normal visual processes.

Progress:
This grant is new in FY91.

TITLE: 6th European Conference on Eye Movements

PRINCIPAL INVESTIGATOR: Erik DeCorte
Katholieke Universiteit Leuven
Laboratorium voor Experimentele Psychologie
Leuven, Belgium
(32)(16) 286099

R&T PROJECT CODE: 4422563 CONTRACT NO: N0001491J1355

Objective:
The conference will encourage multidisciplinary discussion of methodological and theoretical aspects of eye movements with special emphasis on behavioral and psychological processes underlying human information processing. American and European scientists will be brought together to exchange research findings on visual attention, perception, and cognition as well as specific measurement techniques.

Approach:
The conference will be organized into separate slide and poster sessions with six invited lectures over four days. Two of the invited speakers will be American. The invited lectures and selected papers will be published as conference proceedings.

TITLE: The Functional Architecture of Visual Object Recognition: Cognitive and Neuropsychological Studies

PRINCIPAL INVESTIGATOR: Martha J. Farah
Carnegie-Mellon University
Psychology Department
(412) 268-2091

R&T PROJECT CODE: 442k004 CONTRACT NO: N0001491J1546

Objective:
The objective is to evaluate competing theories of the modular organization of higher visual processes and their contribution to cognitive processes involved in object recognition and reading.

Approach:
Normal subjects and neurological patients with specific impairments in high-level visual processes will be studied. Four series of experiments examine: 1) orientation invariance, 2) configurational encoding, 3) visual encoding of words, and 4) the relationship between coding of words and nonverbal visual stimuli.

Progress:
This grant is new in FY91.

TITLE: The Neural Bases of Higher Vision: The 24th Carnegie Symposium on Cognition

PRINCIPAL INVESTIGATOR: Martha J. Farah
Carnegie-Mellon University
Psychology Department
(412) 268-2789

R&T PROJECT CODE: 4422565 CONTRACT NO: N0001491J1395

Objective:
The aim of the meeting is to exchange information and perspectives among neuroscientists, neuropsychologists, and cognitive scientists studying human visual information processing to provide a needed evaluation of the contribution of neurobiological evidence to cognitive theory.

Approach:
A three-day workshop will be conducted for a small group of leading researchers in human visual information processing. Sessions will focus on object representations, category-specificity in visual recognition, reading, covert recognition, and visual attention. Invited lectures will be published as conference proceedings.

TITLE: Brainprints: Computer Generated Maps of the Human Cerebral Cortex in Vivo

PRINCIPAL INVESTIGATOR: Michael S. Gazzaniga
Dartmouth College
Departments of Psychiatry and Psychology
(603) 646-8833

R&T PROJECT CODE: 4422557 CONTRACT NO: N0001489J3035

Objective:
The purpose of the work is to further develop computational methodology for converting NMR scan data about human brain damage into a functionally significant mapping onto the computationally "unfolded" surface of the cerebral hemisphere for the purpose of more precisely specifying the relationships between physical damage to the brain and functional consequences for cognitive capacities.

Approach:
Computer programs will be developed for producing flat maps and 3-D representations of the cortex from NMR data. The specifics of physical damage in neglect patients will be correlated with the extent and nature of the functional deficits they display. The reliability of the data conversion process will be investigated.

Progress:
Using a common underlying database of contours and label information both 2-D flat maps and three dimensional models of cortical NMR data have been developed. Computer aided contour extraction is used to develop that database from NMR image data. Automated contour extraction is available but has not proved as accurate as desired. A menu-driven facility for anatomical labelling is available. The 3-D model supports precise computation of cortical areas. Test versions of the system have now been made available to three other research labs.

Report:
Jouandet, M.L., Tramo, M.J., Herron, D.M., Hermann, A., Loftus, W.C., Bazell, J. and Gazzaniga, M.S. (1989) Brainprints. J. Cognitive Neuroscience, 1, 88-116.

TITLE: Functional Cortical Networks of Human Working Memory

PRINCIPAL INVESTIGATOR: Alan S. Gevins
EEG Systems Laboratory
(415) 957-1600

R&T PROJECT CODE: 442k005 CONTRACT NO: N0001491J1804

Objective:
Event-related brain potentials will be used to determine the specific neural substrates and temporal patterns of brain activity subserving spatial and verbal working memory functions in normal human subjects.

Approach:
Distributed patterns of event-related brain potentials in normal human subjects will be recorded from multiple electrode sites during verbal and spatial working memory tasks and non-memory control conditions. Subsequent analyses, aided by anatomical data from magnetic resonance images, will provide 3-dimensional representations of sequential patterns of neural coactivation during perceptual, motoric, and cognitive components of the behavioral tasks.

Progress:
This grant is new in FY91.

TITLE: Functional Mapping of Working Memory Systems in Nonhuman Primates

PRINCIPAL INVESTIGATOR: Patricia Goldman-Rakic
Yale University
Neuroanatomy Department
(203) 785-4689

R&T PROJECT CODE: 442k003 CONTRACT NO: N0001491J1251

Objective:
The objective is to identify the neural substrates underlying spatial, form, and color working memory in behaving primates.

Approach:
Anatomical and behavioral techniques will be used to investigate the neural representation of different forms of visual and spatial working memory in the monkey brain. Monkeys will be trained in tasks that require them to maintain different kinds of information in working memory. A double-labeling technique will localize metabolic activity in the brain during different behavioral tasks within the same monkey. This innovative anatomical technique will provide a fine-grain analysis necessary to distinguish separate neural populations within the same cortical field.

Progress:
This grant is new in FY91.

TITLE: Understanding the Immediate Interaction Cycle Using the SOAR Unified Theory of Cognition

PRINCIPAL INVESTIGATOR: Bonnie John
Carnegie-Mellon University
School of Computer Science
(412) 268-7182

R&T PROJECT CODE: 4422556 CONTRACT NO: N0001489J1975

Objective:
To extend the SOAR model of human cognitive architecture to account for the way in which interaction with perceivable and modifiable displays in the environment -- such as diagrams or computer displays -- serves to augment the limited working memory of human problem solvers and decision makers.

Approach:
Videotape protocols with good chronometric data will be collected while people perform tasks which involve constructing and modifying displayed objects. The information in the videotapes will be the basis for constructing a simulation model of this "immediate interaction cycle" within the SOAR theory of cognitive architecture.

Progress:
Successful GOMS-like models have been developed for two different situations involving immediate interaction with a visual display: searching for information in a computer browser and rapid interaction in a video-game. Although superficially the first seems user-driven and the second display driven, both can be accounted for by similar GOMS-like models. In the case of the video game, a task analysis based on the instruction booklet and additional reasoning about the goals of the interaction proved sufficient to produce a good model of expert behavior. The model involves both function level and keystroke level operators; prediction of expert behavior at the function level was very good.

Report:
John, B.E., Vera, A.H., Newell, A. (1991) Toward Real-Time GOMS. Technical Report, School of Computer Science, Carnegie-Mellon University.

TITLE: Imaginal Strategies in Inductive Reasoning: Evidence from PET

PRINCIPAL INVESTIGATOR: John Jonides
Regents of the University of Michigan
Department of Psychology
(313) 763-3272

R&T PROJECT CODE: 442k006 CONTRACT NO: N0001491J1713

Objective:
The intent of this project is to use PET scan evidence concerning the localization of brain activity during human reasoning to test current hypotheses about the nature and differentiation of the symbolic and visual processes that may be used in reasoning.

Approach:
Subjects will be trained to solve inclusion and base rate reasoning problems through the use of either symbolic processes or visual (imaginal processes). PET scan data concerning associated brain activity will be collected while subjects perform these reasoning tasks.

Progress:
This grant is new in FY91.

TITLE: PET Studies of Components of High-Level Vision

PRINCIPAL INVESTIGATOR: Stephen M. Kosslyn
Harvard College
Psychology Department
(617) 495-3932

R&T PROJECT CODE: 442k001 CONTRACT NO: N0001491J1243

Objective:
The objectives are to measure metabolic activity within the human brain during recognition and naming of visual objects and to test specific features of a cognitive model of high-level visual processes.

Approach:
Differential cerebral blood flow in the normal human brain will be measured by positron emission tomography (PET) as a marker for neural metabolic activity associated with specific mental processes in visual object recognition and naming. In the first experimental series, the neural substrates for proposed cognitive processes will be investigated by manipulating the degree of task difficulty along a single cognitive dimension found to be an independent additive process from previous reaction-time experiments. The spatial pattern of neural activation during an easy task will be subtracted from the PET scan obtained in the more difficult condition. In the second series, additive cognitive processes will be manipulated to test the dynamics of local cerebral blood flow and the assumption of independent cerebral processes in cognition.

Progress:
This grant is new in FY91.

TITLE: BRAINMAP -- A Database of Functional Neuroanatomy Derived From Human Brain Images

PRINCIPAL INVESTIGATOR: Jack L. Lancaster
Health Science Center at San Antonio
Research Imaging Center
(512) 567-5549

R&T PROJECT CODE: 442k007 CONTRACT NO: N0001491J1991

Objective:
This project aims to develop database systems which will make it possible to compare and combine research results on the functional anatomy of the human brain, both neuropsychology research on the effects of brain damage and functional imaging data from normal subjects. Two systems will be developed, a Macintosh/SuperCard database for results in the published literature and a Sun-based system for near-raw-data results of PET imaging studies. The latter will be interfaced to a PET image display/analysis environment.

Approach:
Data on brain locations of lesions or of foci of PET activity will be indexed in a 3-D coordinate system that has been previously developed for the analysis and combination of PET scan data, in addition to being indexed by conventional anatomical nomenclature. Behavioral conditions will be described in a multi-level list-driven schematization of the experimental conditions employed, in order to maximize clarity and objectivity. In order to reduce the PET image data to records of manageable size, it is partially reduced by examining regions showing change in cerebral bloodflow that are statistically significant outliers from the noise distribution.

Progress:
This grant is new in FY91.

TITLE: Cognitive Components of Information Coordination

PRINCIPAL INVESTIGATOR: James W. Pellegrino
Vanderbilt University
Learning Technology Center
(615) 322-7311

R&T PROJECT CODE: 4422570 CONTRACT NO: N0001491J1709

Objective:
The objective is to determine how the apparent role of "coordinative ability" in determining performance on complex tasks depends upon the degree of difficulty and/or of individual proficiency in the performance of individual component tasks.

Approach:
Experiments will be conducted in which the impact of several days of practice with feedback upon the apparent importance of coordinative ability to overall complex task performance will be assessed. Practice on the separate task components will be compared to practice on the complex coordinative task.

Progress:
This grant is new in FY91.

TITLE: Conference on the Architecture of Intelligent Systems

PRINCIPAL INVESTIGATOR: Zenon W. Pylyshyn
Rutgers University
Department of Psychology
(203) 932-5943

R&T PROJECT CODE: 4422572 CONTRACT NO: N0001491J1851

Objective:
This conference will consider what the various contributing disciplines of cognitive science -- psychology, computer science, philosophy, neuroscience, linguistics -- can contribute to the common problem of understanding computational architectures that support intelligence.

Approach:
A three-day workshop involving leading figures from the various disciplines will be convened. Position papers will be distributed in advance, in order to foster interdisciplinary discussion at the workshop itself. Either a published volume or a summary report by the conference organizers is anticipated.

TITLE: Laboratory for Localizing Dynamic Cognitive Processing

PRINCIPAL INVESTIGATOR: Walter Schneider
University of Pittsburgh
Department of Psychology
(412) 624-7061

R&T PROJECT CODE: 4422569 CONTRACT NO: N0001491J1708

Objective:
The purpose of this project is to establish a laboratory facility for high-density surface recording of brain electrical activity associated with dynamic cognitive processes, such as those of attentional control.

Approach:
An existing laboratory facility at Yale University for doing this type of recording will be replicated at the University of Pittsburgh. A 64 channel recording system will be built to provide the density of data required for good localization estimates. Data reduction software will be obtained from the Yale research group as well. Initial studies will be conducted using well-established cognitive experimental paradigms with which the PI is highly experienced, in order to develop a general methodology for research of this kind.

Progress:
This grant is new in FY91.

TITLE: U.S. Participation in Workshop on Hybrid Models of Cognition

PRINCIPAL INVESTIGATOR: Walter Schneider
University of Pittsburgh
Department of Psychology
(412) 624-7061

R&T PROJECT CODE: 442f014 CONTRACT NO: N0001491J1724

Objective:
This project provides U.S. participants the opportunity to participate in an international forum in which the issues surrounding hybrid architectures for cognition can be discussed. These architectures combine more traditional symbolic components with connectionist components.

Approach:
A 2-day workshop with a limited invited attendance is being held at the Royal Society of London, organized by the three principal research funding agencies of the U.K., as part of their initiative in cognitive science and human-computer interaction.

COGNITIVE SCIENCE

KNOWLEDGE, SKILL AND EXPERTISE

TITLE: Symposium on Reading Research in Relation to Sentence Processing

PRINCIPAL INVESTIGATOR: Thomas G. Bever
University of Rochester
Department of Psychology
(716) 275-3213

R&T PROJECT CODE: 4422567 CONTRACT NO: N0001491J1681

Objective:
The objective of the symposium is to conduct discussions which will better relate psycholinguistic research on the processing of isolated sentences to the larger context of research on reading in general, from the word recognition level to large discourse structures.

Approach:
A symposium with this purpose will be conducted in conjunction with the annual conference on sentence processing research. An edited volume is expected to result.

TITLE: Application of CAPS Modeling to Strategy Competition and Flexibility in Discourse Comprehension

PRINCIPAL INVESTIGATOR: Susan R. Goldman
Vanderbilt University
Learning Technology Center
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R&T PROJECT CODE: 442f013 CONTRACT NO: N0001491J1769

Objective:
The objective is to use the CAPS modeling system to model the reading processes of bilingual (non-native speakers of English) students, in order to provide insight into the learning difficulties that persist despite apparent fluency in English.

Approach:
Data from a previous ONR contract that studied the reading processes of bilingual students will be used. The CAPS cognitive modeling system developed by Carpenter and Just will be used to model the processes of strategy selection and competition that were hypothesized to account for that data, providing a stronger test of those conclusions. Software aids to the user will be developed to augment the existing CAPS system, making model development more efficient and more accessible to researchers who are not high in computer expertise.

Progress:
This grant is new in FY91.

Report: [resulting from earlier grant]
Goldman, S.R. and Saul, E.U. (1990a) Flexibility in text processing: A strategy competition model. Learning and Individual Differences., 2, 181-219.

Goldman, S.R. and Murray, J.D., (in press) Knowledge of connectors as cohesion devices in text: A comparative study of native English and ESL speakers. Journal of Educational Psychology.

TITLE: Development and Enhancement of a Model of Performance and Decision Making Under Stress in a Real-Life Setting

PRINCIPAL INVESTIGATOR: Colin F. MacKenzie
University of Maryland at Baltimore
Department of Anesthesiology
(301) 328-3418

R&T PROJECT CODE: 4422568 CONTRACT NO: N0001491J1540

Objective:
The objective is to produce a process model of medical decision making in a real-life stressful medical task environment of trauma patient resuscitation and anesthesia. The effects of various stress factors such as fatigue and patient workload upon the quality of decision performance will be determined.

Approach:
Model building will begin with considerations derived from task analyses and decision trees based on expert judgment of ideal decision performance. The model will be evaluated, refined and modified based on the analysis of performance data obtained from the analysis of videotapes of actual trauma patient resuscitation and anaesthesia. The VideoNoter system for videotape analysis will be used. Stressors in the task environment will be identified and their effect on team and individual performance will be measured. The effects of fatigue, mental workload, and team interaction in sharing and shedding tasks, and the effect of physicians' experience will be investigated.

Progress:
This grant is new in FY91.

TITLE: Analysis of the Organization of Lexical Memory

PRINCIPAL INVESTIGATOR: George A. Miller
Princeton University
Department of Psychology
(609) 452-5973

R&T PROJECT CODE: 442c026 CONTRACT NO: N0001490J1692

Objective:
The objective is to develop a novel kind of electronic lexical reference work, an augmented thesaurus, that is built upon a model of human lexical memory, in order to facilitate tasks in which the relationships among word meanings are important: design of technical and instructional documents, reading and use of such documents, and natural language computer interfaces.

Approach:
A computer simulation of human lexical memory is being constructed. Lexical concepts are represented as synonym sets. These lexical concepts are being extensively interconnected by networks of meaning relationships: opposition of meaning, part-whole relations, subordination relations, etc.

Progress:
Appropriate data structures have been developed to represent the relationships that exist among the nouns in English, among the adjectives (a novel development), and also among the verbs, which are related by entailment relationships (also a somewhat novel development). Approximately 55,000 word forms representing 42,000 meanings or synonym sets are now incorporated in the database. Computer interfaces to the databases, search routines and tools for building WordNet have also been developed. Versions exist to run on Sun workstations, PC's and MacII computers -- the intent is that the database itself be entirely machine independent. A "lexical filter" to aid in improving document readability is nearly complete.

Report:
Special issue of International Journal of Lexicography (1990), 3, 235-312.

Outside Funding:
This project was funded by the Manpower, Personnel and Training Research Program of OCNR and by the Navy Personnel Research and Development Center.

TITLE: WORDNET: A Lexical Database for English

PRINCIPAL INVESTIGATOR: George A. Miller
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Cognitive Science Laboratory
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R&T PROJECT CODE: 4422566 CONTRACT NO: N0001491J1634

Objective:
The objective of this project is to extend WordNet, a semantic lexical resource for natural language computing, to incorporate contextually-based strategies for the disambiguation of word senses. In addition, the appropriateness and utility of the WordNet database for a variety of computational linguistics applications will be explored.

Approach:
WordNet represents the semantics of English as a network of relationships that are semantically important in human word knowledge: relationships of semantic similarity and opposition of meaning, superordinate and subordinate relations, and part-whole relationships, among others. In the present effort, large bodies of textual information will be processed to determine how context serves to differentiate the different meanings (senses) that the same superficial word form may have, and ways will be sought to effectively represent that contextual information within the network structure of WordNet. Various applications will be explored in order to test the appropriateness and utility of the representation of lexical information.

Progress:
see previous grant

Outside Funding:
This project is jointly funded by the Defense Advanced Research Projects Agency and the ONR Cognitive Science Program.

TITLE: Design Problem Solving

PRINCIPAL INVESTIGATOR: Peter L. Pirolli
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School of Education
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R&T PROJECT CODE: 4422550 CONTRACT NO: N0001488K0233

Objective:
The research objective is to conduct studies of the design problem-solving process which will yield data for developing a model that characterizes the contents of the problem space and the problem-solving processes involved in design tasks, focusing on generative processes of formulating and modifying problem goals and plans and on using information from multiple sources. The final phase of the project is focused on understanding the role of visual representations in design problem solving.

Approach:
The approach uses a variety of design tasks, emphasizing instructional design, but including other types of design for purposes of comparison. Subjects are asked to design instruction, given certain goals and constraints. Empirical studies and psychological experiments will be conducted in which goals and constraints on design problems are manipulated, and in which the availability of knowledge relevant to the design task is varied. Some aspects of design problem solving performance are being modeled in the SOAR cognitive architecture.

Progress:
Using the method of protocol collection across diverse design tasks in different domains, a process of design problem solving in general was described and differentiated from typical processes of problem solving in well-structured domains. The design process of a single instructional design episode was simulated in the SOAR cognitive architecture. Many interesting observations were made about the use of different symbol systems, including informal drawings and more formal visual representations, leading to several hypotheses about the problem-solving roles of differing representation systems. These are now being pursued.

Reports:
Goel, V. (1991) The structure of design problem spaces. (Tech. Rep. No. DPS-3). University of California, Berkeley. Goel, V. (1991) Specifying and classifying representational systems: A critique and proposal for cognitive science. (Tech. Rep. N. DPS-2) University of California, Berkeley.

Goel, V. & Pirolli, P. (1989) Motivating the notion of generic design within information processing theory: The design problem space. AI Magazine, 10, 19-36.

TITLE: A Case-Based Approach to Planning and Decision Making

PRINCIPAL INVESTIGATOR: Colleen Seifert
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Psychology Department
(313) 763-0210

R&T PROJECT CODE: 442f009 CONTRACT NO: N0001491J1128

Objective:
The objective of this project is to answer a variety of questions about the functioning of human memory that arise in the course of building AI models of case-based reasoning, problem solving and decision making: how the representation of information during initial learning affects the ability to retrieve and use it in new situations, how information that is retrieved depends upon the relation to pending goals in problem-solving activity, how prior cases are retrieved and used in decision making and explanation.

Approach:
A variety of experimental paradigms appropriate to these questions are being used in the research, ranging from simple reports of reminding of past cases to the observation of actual use during an on-going decision-making or problem-solving tasks. The relation of features available at original learning to cues available at the time of retrieval is manipulated.

Progress:
Probably the most significant result of the research to date is a set of studies which will require reinterpretation of a famous old finding in psychology, the Zeigarnik effect -- which says that incomplete tasks are better remembered than completed ones. Interrupting people in the course of problem solving, Seifert has twice found the opposite result. Further investigation indicates that the "effect" should probably be attributed simply to exposure time. Experimenter-determined interruptions typically result in short exposure time, whereas subjects are likely to have spent relatively larger amounts of time working on the problems that they failed to solve in an available testing period (presumably the condition of the Zeigarnik experiment.)

Report:
McKoon, G., Ratcliff, R. & Seifert, C.M. (1990) Making the connection: Generalized knowledge structures in story understanding. J. of Memory and Language.

TITLE: System Dynamics and Computer Modeling Expertise: A Research Inquiry

PRINCIPAL INVESTIGATOR: Mark Siegel
University of the District of Columbia
Department of Psychology
(202) 282-2152

R&T PROJECT CODE: 4422564 CONTRACT NO: N0001491J1360

Objective:
The project will identify key concepts in the systems dynamics approach to computer modeling of phenomena, will determine how those concepts are related in the understanding of experts in the field, and will determine how expertise develops during instruction.

Approach:
Publications on systems dynamics will be used to develop a candidate list of key concepts. Experts in the field will be consulted to review and possibly modify the list. Computerized presentations of pairs of concepts will be used to elicit judgements of relatedness from a group of expert subjects and these data will be analyzed using the Pathfinder program to infer underlying conceptual networks. Provided this initial research effort is successful, additional subject groups varying in expertise will be studied in the same manner.

Progress:
This grant is new in FY91.

COGNITIVE SCIENCE

LEARNING AND INSTRUCTION

TITLE: The Improvement of Text Readability by Phrase-Sensitive Formatting

PRINCIPAL INVESTIGATOR: Thomas G. Bever
University of Rochester
Department of Psychology
(716) 275-3213

R&T PROJECT CODE: 4428016 CONTRACT NO: N0001489J3032

Objective:
The research objective is to determine whether text formatted so as to indicate phrase boundaries, using an automated algorithm to determine phrase boundaries, will improve the readability of text.

Approach:
Carefully designed experiments with community college students, and possibly with Navy recruits or trainees, of different levels of reading ability will be conducted to examine the influences and interactions of several variables on reading speed, comprehension, and retention. The variables include reading ability, text complexity, phrase size, space size, and retention interval; other variables suggested by these experiments may also be studied. The phrase size and space size variables will be controlled by an algorithm for automatically formatting text which has been developed and tested by the PI.

Progress:
Several hundred subjects have been tested on phrase structure formatted essay comprehension items. Formatting led to significantly better performance on test items, as well as faster reading times. Effects are largest for below-average readers and difficult essays. Texts treated to maximize the evenness of the number of words also improve reading performance; in this case, the advantage is primarily seen for above average readers. Results from special subject groups suggest that formatting is proportionately much more helpful to deaf readers and readers from bilingual backgrounds. Preliminary results from an experiment comparing formatted and non-formatted text in the context of a vocational school course indicate a significant advantage in retention and course grades for students receiving the specially formatted text.

Report:
Bever, T., Jandreau, S., Burwell, B., Kaplan, R., Zaenen, Spacing printed text to isolate major phrases improves readability. Visible Language (in press).

Outside Funding:
Funding for this project was provided by the ONT Code 222 and NPRDC.

TITLE: The Induction of Mental Structures While Learning to Use Symbolic Systems

PRINCIPAL INVESTIGATOR: Thomas G. Bever
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Department of Psychology
(716) 275-3213

R&T PROJECT CODE: 442f005 CONTRACT NO: N0001488K0336

Objective:
The research objective is to explore the emergence of implicit mental structures (such as linguistic grammars or mental models of machine operations) during the solution of explicit problems. The investigator has proposed a problem-solving theory of the acquisition of implicit structure which he will test with a series of experiments using an artificial symbolic structure.

Approach:
A series of experiments will be conducted to test hypotheses derived from the investigator's theory of the formation of implicit mental structures during the solution of explicit problems. In addition to attempting to improve the efficiency of the basic paradigm used in a pilot study, the experiments will investigate: implications, for learning, of conflicting regularities within mapping systems for internal perception and production mechanisms; differences between perception and production in learning; and extensions of the paradigm to investigate implications of fuzzy feedback, effects of error messages, and modelling of the acquisition of behavior and structure.

Progress:
Six new experiments were run in which the results of the experiments that formed the basis of the proposal were replicated, and improved understanding of the conditions necessary to obtain those results was achieved. Computer programs to improve the quality of experimental stimulus presentations have been developed. A preliminary version of a connectionist learning model to account for the results has been developed. A new paradigm, based on the study of map learning, has been developed for investigating induction of abstract mental representations.

TITLE: Understanding Mechanical Systems Through Computer Animation and Kinematic Imagery

PRINCIPAL INVESTIGATOR: Patricia A. Carpenter
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Department of Psychology
(412) 268-2091

R&T PROJECT CODE: 4428017 CONTRACT NO: N0001489J1218

Objective:
Determine how computer animations can be used in training to enhance understanding of the operation of mechanical devices.

Approach:
Conduct behavioral experiments in which device and display characteristics are systematically varied, while eye movements are monitored and subject ability to answer questions about device operation is measured. Build computer simulation models of the process of device understanding that account for these data.

Progress:
Experiments have been conducted which reveal much about the processes by which people develop or fail to develop understanding of the operation of devices. Results of experiments exploring the value of animation suggest that it is not as helpful in aiding understanding as had been hoped and that it may actually be detrimental for subjects of high mechanical ability.

Report:
Hegarty, M., and Just, M.A. (1989). Understanding machines from text and diagrams. In H. Mandl and J.R. Levin (Eds.), Knowledge acquisition from text and picture. North Holland: Elsevier Science Publisher, B.V.

Outside Funding:
Funds for this project are provided by ONT Code 222.

TITLE: Predicting What People Learn from Examples

PRINCIPAL INVESTIGATOR: Richard Catrambone
Georgia Tech Research Corporation
Department of Psychology
(404) 894-2682

R&T PROJECT CODE: 4422561 CONTRACT NO: N0001491J1137

Objective:
This project aims to understand how problem solving examples can be designed to bring about the most efficient and effective learning of appropriately generalized problem solving skills.

Approach:
A production system analysis of the problem-solving skills will be conducted in order to provide a systematic basis for the design of examples. Several hypotheses concerning the conditions which result in the learner identifying and recognizing the subgoals that organize problem-solving performance will be tested in experiments which provide learners with appropriately designed example problems.

Progress:
This grant is new in FY91.

TITLE: Computer Generation of Complex Tutorial Dialogues

PRINCIPAL INVESTIGATOR: Martha Evens
Illinois Institute of Technology
Department of Computer Sciences
(312) 567-5153

R&T PROJECT CODE: 4422554 CONTRACT NO: N0001489J1952

Objective:
The objective of this grant is to learn how to produce intelligent computer-generated tutorial dialogue.

Approach:
The tutorial guidance provided by expert human tutors working with students using an instructional simulation will be recorded and analyzed. The Lexical Functional grammar of Kaplan and Bresnan will be used with lexical selection based on Even's previous lexical work. In addition, information taken from the student model of the tutoring system will be used to individualize the tutorial dialog appropriately for student needs.

Progress:
Both face-to-face and keyboard-to-keyboard human tutoring sessions have been recorded and analyzed, a computer program having been developed for managing and recording the latter. Debriefing sessions have been used to extract both tutoring rules and student modeling rules from the expert tutors participating in the project, who were found to differ significantly. It was found that tutors plan their discourse in much larger chunks than is usual for current artificial language generation. A limited language generation capability that adapts to several features of the current situation has been developed, as has a capability to process imperfect input from students.

Reports:
Michael, J.A., Rovick, A.A., Evens, M., & Kim, N. (1990) A smart tutor based on a qualitative causal model. Proceedings of the AAAI Spring Symposium on Knowledge-Based Environments for Learning and Teaching, Stanford, March 27-29, 112-117.

Zhang, Y., Evens, M., Michael, J. & Rovick, A. (1990) Extending a knowledge base to support explanations. Proceedings of the Third IEEE Conference on Computer-based Medical Systems, June 4-6, Chapel Hill, North Carolina, 259-266.

TITLE: Memory and Use of Examples in Problem Solving

PRINCIPAL INVESTIGATOR: Jeremiah M. Faries
Northwestern University
Psychology Department
(312) 491-0347

R&T PROJECT CODE: 442f012 CONTRACT NO: N0001491J1742

Objective:
The objective of this project is to study the way in which students draw upon instructional text, instructional example problems, and past problem-solving experiences in order to solve new problems in the process of acquiring a problem-solving skill. It is expected that this will provide insights into the way in which instruction for problem-solving skill can be best designed.

Approach:
The BATBOOK computer environment will be used to observe and record the way in which students refer back to instructional materials and past problem-solving experiences in the course of learning a problem-solving skill. The nature of the instructional materials provided will be experimentally varied in order to determine the relative contributions of instructional text, instructional worked examples, and practice problem solving to the acquisition of problem-solving skills. This project is part of a collaboration with Brian Reiser of Princeton University (442f010); Faries will do a large proportion of the empirical data collection, using the more diverse subject population available at Northwestern, as compared to Princeton.

Progress:
This grant is new in FY91.

TITLE: Analogical Processes and Learning in Physical Domains

PRINCIPAL INVESTIGATOR: Dedre Gentner
University of Illinois
Department of Psychology
(217) 333-2186

R&T PROJECT CODE: 442f007 CONTRACT NO: N0001489J1272

Objective:
The goal is to construct and test a general theory of analogical thinking as it occurs in both learning and reasoning. Parametric investigations of the detailed assumptions of the formal model of this theory, the Structure Mapping Engine, will be conducted in order to more precisely specify detailed aspects of the theory. Aspects of the application of the theory will be automated in order to increase its objectivity, and its application to the new and more complex domain of the learning of causal models will be explored.

Approach:
Psychological and computational experiments will be conducted in parallel to determine what computational theory can best account for human data on learning, analogy formation, and analogy evaluation. The learning of causal models for physical phenomena in artificial worlds will be an important aspect of the psychological investigations.

Progress:
A study has been completed on the relationship of verbalization of a task and ability to transfer that task; results indicate that verbalization prior to transfer attenuated the transfer difficulty associated with conflicting superficial similarities. A programmable system also has been built for experimenting with two-stage models of similarity-based access from long-term memory.

Report:
Clement, C. & Gentner, D. (1990, in press) Systematicity as a selection constraint in analogical mapping. Cognitive Science.

Falkenhainer, B., Forbus, K.D. (1989/1990) The structure-mapping engine: algorithm and examples. Artificial intelligence, 41, 1-63.cs learning and instruction

TITLE: Questioning Mechanisms During Complex Learning

PRINCIPAL INVESTIGATOR: Arthur C. Graesser
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(901) 678-2742

R&T PROJECT CODE: 4422548 CONTRACT NO: N0001490J1492

Objective:
The objective of the research is to extend the QUEST computer simulation model of question answering to account for the interaction between human tutors and students. QUEST now models the process by which answers are generated from conceptual graph structures of knowledge.

Approach:
The interactions of human tutors and students during instruction in mathematical word problem solving and instruction in scientific research methods will be recorded, transcribed, and analyzed. Changes in the pattern of questioning over time will be related to existing theories of the process of knowledge acquisition. The QUEST computer simulation model will be extended to account for question asking and answering in the tutorial situation, with particular emphasis on pragmatic features of interaction related to shared and differential knowledge and goals.

Progress:
Extensive collection of data on tutorial interactions of various types has occurred and analysis with respect the nature of the questions and answers generated by the tutor and tutee is in process. A number of publications of previously completed research are in press.

Report:
Graesser, A. C. & Franklin, S. P. QUEST: A cognitive model of question-answering. Discourse Processes (in press)

Golding, J.M., Graesser, A.C. & Millis, K.K. What makes a good answer to a question? Testing a psychological model of question answering. Discourse Processes (in press)

TITLE: Explanation-based Knowledge Acquisition of Electronics

PRINCIPAL INVESTIGATOR: David Kieras
Regents of the University of Michigan
Technical Communication Program
(313) 763-6739

R&T PROJECT CODE: 442f002 CONTRACT NO: N0001488K0133

Objective:
To advance understanding of the process by which human trainees learn from technical training materials.

Approach:
An AI learning system using an explanation-based learning approach is developed to learn from instructional texts and diagrams such as those used to train electronics technicians. Progressively more complex circuit schemata are built on the foundations of earlier rules . Cognitive models of these processes are developed that provide predictive metrics for human learning, and are experimentally evaluated.

Progress:
The machine learning model of learning from text and diagrams has been constructed. It revealed a number of points of difficulty such as instructional problems in which the constitutent simpler circuit schemata cannot be treated as "black-box" input/output devices but in which "glass-box" reasoning about internal functions is required to reason about the correct answer. A preliminary experiment has been conducted in which the number of machine cycles required for processing the instruction was strongly predictive of human time requirements. Additional experiments are in process.

Report:
Mayer, J.H. (1990) Explanation-based knowledge acquisition of schemas in practical electronics: A machine learning approach. Doctoral dissertation, University of Michigan.

TITLE: Schemas in Problem Solving: An Integrated Model of Memory, Learning, and Instruction

PRINCIPAL INVESTIGATOR: Sandra P. Marshall
San Diego State University Foundation
Department of Psychology
(619) 594-2695

R&T PROJECT CODE: 442c010 CONTRACT NO: N0001490J1143

Objective:
The project objective is to produce a psychological model of the teaching and learning of mathematical problem-solving skills.

Approach:
The underlying semantic structures, or schemas, of mathematics word problems used in school texts, Navy remedial courses, and standardized tests have been analyzed and related to item difficulty in mass test data. Computer simulations of problem-solving knowledge and skill will provide the basis for experimental instruction, and the process of learning will also be modeled in a computer simulation. Further instructional/learning experiments will be conducted to test aspects of the computer simulation model.

Progress:
A detailed theory of problem schemata has been developed and shown to cover all problems used in diverse instruction, including Navy remedial math instruction. Computerized instruction based on the schema theory has been developed and used to conduct several instructional experiments in which detailed protocols have been collected to probe what is being learned. Three different models have been developed to test the schema theory against these data: a semantic network model that predicts student performance, a perceptron-like connectionist model which has independently produced classifications consistent with the schema theory, and a connectionist competitive learning model which also did so with rather few trials. The project as a whole is to be reported in book form.

Report:
Marshall, S. (1990) The assessment of schema knowledge for arithmetic story problems. In: Assessing Higher Order Thinking in Mathematics. G. Kulm (Ed) Washington, DC: AAAS.

TITLE: Computer Generation of Complex Tutorial Dialogues: Rush Participation

PRINCIPAL INVESTIGATOR: Joel A. Michael
Rush Medical College
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(312) 942-7120

R&T PROJECT CODE: 442f011 CONTRACT NO: N0001491J1622

Objective:
The objective of this grant is to learn how to produce intelligent computer-generated tutorial dialogue.

Approach:
The tutorial guidance provided by expert human tutors working with students using an instructional simulation will be recorded and analyzed. The Lexical Functional grammar of Kaplan and Bresnan will be used with lexical selection based on Evens' previous lexical work. In addition, information taken from the student model of the tutoring system will be used to individualize the tutorial dialogue appropriately for student needs. This project is in a collaboration with Evens.

Progress:
Both face-to-face and keyboard-to-keyboard human tutoring sessions have been recorded and analyzed. Debriefing sessions have been used to elicit both tutoring rules and student modelling rules from the expert tutors participating in the project, who were found to differ significantly. It was found that tutors plan their discourse in much larger chunks than is usual for current artificial language generation. A limited language generation capability that adapts to several features of the current situation has been developed, as has a capability to process imperfect input from students.

Report:
Kim, N., Evens, M., Michael, J.A., & Rovick, A.A. (1989) An intelligent tutoring system for circulatory physiology. In H. Maurer (Ed.) Computer assisted learning. Berlin: Springer-Verlag, 254-266. See also reports listed under Evens.

TITLE: Human Plausible Reasoning and Learning: Development of a Computational Model and a Unified Theory.

PRINCIPAL INVESTIGATOR: Ryszard S. Michalski
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(703) 323-2713

R&T PROJECT CODE: 442f006 CONTRACT NO: N0001490J4059

Objective:
This research aims to provide computational models of the way in which humans learn and reason with imprecise, incomplete and/or indirectly relevant premises.

Approach:
A unified theory of human plausible reasoning and inductive learning will be developed in the form of a computational model. This will build upon the Collins and Michalski "core theory" of human plausible reasoning, upon Michalski's "two-tiered method" for representing flexible context-dependent concepts, and Medin's "multi-criterion patch model" of inductive learning. Further experimental tests of human performance will be conducted in order to test the computational theory against human performance.

Progress:
The theory of plausible reasoning was implemented as a computer program, enabling the derivation of predictions of human performance. A series of experiments with human subjects was conducted and analyzed in terms of the concepts and inference rules of the theory. The results support the basic tenets of the theory, demonstrating that the proposed structural organization of knowledge and multi-pattern inference play a crucial role in plausible reasoning.

Report:
Collins, A. & Michalski, R. (1989) The logic of plausible reasoning: a core theory, Cognitive Science, 13, 1-49.

Boehm-Davis, D., Dontas, K. & Michalski, R. (1990) A validation and exploration of the Collins-Michalski theory of plausible reasoning. George Mason University.

TITLE: Explanatory Dialogues in a Complex Real World Domain

PRINCIPAL INVESTIGATOR: Johanna Moore
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Learning Research and Development Center
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R&T PROJECT CODE: 4422571 CONTRACT NO: N0001491J1694

Objective:
This project aims to develop the capability to conduct an explanatory dialog with a trainee learning how to diagnose faults in a complex electronic device.

Approach:
Within the context of an existing maintenance tutor, data will be collected on the way that a human expert responds to trainee questions and provides explanations. Artificial intelligence techniques will be used to emulate this performance. Discourse goals will be identified and the system's information about the situation will be appropriately selected, abstracted and summarized in order to generate a response that meets the standards of human discourse.

Progress:
This grant is new in FY91.

TITLE: Cognitive Function of Theoretical Knowledge in Procedural Learning

PRINCIPAL INVESTIGATOR: Stellan Ohlsson
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Learning Research and Development Center
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R&T PROJECT CODE: 442f008 CONTRACT NO: N0001489J1681

Objective:
The objective is to understand how knowledge of principles in a domain can be used to aid learning and adaptive modification of problem-solving procedures.

Approach:
Computer simulations will be built to determine how principled knowledge can be used to monitor, acquire, and adapt procedures. Two domains in which extensive human problem-solving data are available will be explored -- arithmetic and physics problem solving. Variations in the models will be used to determine how these variations affect the efficiency of learning. In particular, learning mechanisms proposed in various important cognitive theories of learning -- chunking (Newell), knowledge compilation (Anderson) and explanation-based learning (DeJong) -- will be compared for their impact on overall learning performance.

Progress:
Analyses of the human performance data via computational modelling have shown evidence of mechanisms of complex human learning as yet not explored in the field of machine learning.

Reports:
Ohlsson, S. & Rees, E. (1991) Adaptive search through constraint violations. Technical Report, LRDC, University of Pittsburgh.

Ohlsson, S. (1991) The mechanism of restructuring in geometry. Technical Report, LRDC, University of Pittsburgh.

TITLE: Memory and Use of Examples in Problem Solving

PRINCIPAL INVESTIGATOR: Brian J. Reiser
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Department of Psychology
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R&T PROJECT CODE: 442f010 CONTRACT NO: N0001491J1125

Objective:
This project aims to understand how students refer back to past instructional or personal problem solutions in order to solve new problems by processes of analogy.

Approach:
An innovative computerized instructional environment will be used to conduct a variety of experiments in which references to either text example problems or past problem solutions by the student can be tracked and recorded. The record of search attempts will also provide evidence concerning the way in which past experience with problem-solving examples is coded in the student's memory. Various characteristics of the instructional example problems will be experimentally manipulated in order to explore the effect on example accessibility and utility.

Progress:
This grant is new in FY91.

TITLE: Impact of Intelligent Computer-Assisted Instruction

PRINCIPAL INVESTIGATOR: Janet W. Schofield
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Psychology Department
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R&T PROJECT CODE: 442c013 CONTRACT NO: N0001485K0664

Objective:
The objective was to investigate theoretically derived hypotheses about the impact of the introduction of an artificially intelligent tutor on the authority structure of the classroom, on the content of the teacher's role and on various aspects of student behavior.

Approach:
Observations of student and teacher behavior were recorded in geometry classes using Anderson's intelligent tutor of geometry, in control geometry classes, and in other classes using computers for more conventional instruction or for enrichment of gifted students. These were supplemented with interviews of students, teachers, administrators, the developers of the intelligent tutor and others. These were coded into a large data base for analysis in relation to the research questions.

Progress:
With respect to the most central questions, the geometry tutor was found to produce a marked increase in student involvement and effort. Increased competition related to progress through the problems presented by the tutor and decreased embarrassment at mistakes -- due to the privacy provided by the computer tutor -- appeared to contribute to this change. The teacher's role also changed so that the teacher spent relatively more time working individually with low-achieving students. Several reports on aspects of the research have been issued and a book manuscript is in preparation.

Report:
Scholfield, J.W. & Evans-Rhodes, D. (1990) Artificial intelligence in the classroom: The impact of a computer-based tutor on teacher and student behavior. In: Proceedings of the Third International Conference on AI and Education, Amsterdam.

TITLE: A Consortium for Lexical Research

PRINCIPAL INVESTIGATOR: Yorick Wilks
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Computing Research Laboratory
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R&T PROJECT CODE: 4428029 CONTRACT NO: N0001491J1440

Objective:
This project aims to provide lexical resources for natural language computing and to make those resources available to the computational linguistics research community.

Approach:
Lexical resources will be sought from members of the computational linguistics community. These will include word lists, dictionaries, statistical data, etc., as well as tools for the analysis of lexical and text data. These resources will be included in a computerized repository and will be made available to members of the computational linguistics research community, under the licensing agreements required by the contributors of the information. A theory-neutral format for the representation of lexical data will be sought.

Progress:
This grant is new in FY91.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Automating a Detailed Cognitive Task Analysis For Structuring Curriculum

PRINCIPAL INVESTIGATOR: Kent E. Williams
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Dept. of Industrial & Systems Engineering
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R&T PROJECT CODE: 4428031 CONTRACT NO: N0001491J1500

Objective:
This project aims to produce an automated aide to the process of analyzing a to-be-trained task at the production system level of detail so that a subject-matter expert who is not trained in computer and cognitive science will be able to accomplish such an analysis, a prerequisite to the production of an artificially intelligent training system for that task.

Approach:
The approach will be to automate the process of analysis that was used in the PI's previous successful project building a tutoring system. Analysis is based on a production system theory of the nature of human skill. For example, goals, subgoals, and tasks contributing to the accomplishment of goals are specified. Then methods are specified for the accomplishment of tasks, methods being a set of steps or conditions to be satisfied in accomplishing the task. This analysis process will continue until a set of primitive operations in the vocabulary of the automated aid is reached.

Progress:
This grant is new in FY91.

Outside Funding:
Funds for this project are provided by the ONT Manpower, Personnel and Training Research Program.

COGNITIVE SCIENCE

MODEL-BASED MEASUREMENT

TITLE: Assessing Competence in Electronic Troubleshooting

PRINCIPAL INVESTIGATOR: Gautam Biswas and Susan Goldman
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(615) 343-6204

R&T PROJECT CODE: 4421571 CONTRACT NO: N0001491J1680

Objective:
The objective of this project is to develop an approach to assessment that incorporates (a) student models of concepts and procedures, (b) changes in those models as expertise develops, and (c) theories about different forms of expert performance. This methodology will be validated for expertise in digital electronics.

Approach:
Computational models which simulate troubleshooting performance as a function of troubleshooting strategies and mental models of digital circuit topology, function, and behavior will be constructed. These models will simulate both quantitative and qualitative aspects of problem solving. Machine learning techniques will be employed to generate "buggy" models. And, plan recognition techniques will be employed for model inference.

Progress:
This grant is new in FY91.

TITLE: Job Knowledge Test Design: A Cognitive Science Approach.

PRINCIPAL INVESTIGATOR: Walter C. Borman and David DuBois
Personnel Decisions Research Institute
(813) 974-2492

R&T PROJECT CODE: 4428035 CONTRACT NO:

Objective:
The objective of this project is to explore the viability of improving Marine Corps job knowledge tests by applying methods from modern cognitive science.

Approach:
Job knowledge tests for three Marine Corps domains will be developed and evaluated with job trainees and job incumbents. A key ingredient of the evaluation will be the relationship between measures of job knowledge and measures of hands-on performance. To this end, domains will be selected for which job performance measurement instruments have been developed, and the relationships between performance on the two types of tests will be studied.

Progress:
This grant is new in FY91.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: A Revised Modified Parallel Analysis (MPA) for the Construction of Unidimensional Item Pools

PRINCIPAL INVESTIGATOR: David V. Budescu
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R&T PROJECT CODE: 4428034 CONTRACT NO: N0001491J1666

Objective:
The objectives are to develop a theoretically sound and computationally feasible methodology for assessing the dimensionality of large item pools intended for adaptive administration and for identifying unidimensional subsets of items from large multidimensional pools.

Approach:
First, several modifications to Drasgow's modified parallel analysis (MPA) will be explored: (a) Random generation of correlations from a synthetic population will be replaced by expected correlations under unidimensionality and conditional independence. (b) Separate estimation of the communalities in the two datasets will be replaced by the expected correlation between experimentally independent administrations of each item under conditional independence and unidimensionality. (c) The correlation matrix will be jackknifed by removing one item at a time. And, (d) the closeness of the actual item pool to unidimensionality will be assessed by an approximate t-test based on the jackknifed estimates. Second, these procedures and others based on ratios of eigenvalues will be tested in simulation studies. Third, the viability of jackknife procedures for identifying unidimensional subsets will be examined.

Progress:
This grant is new in FY91.

TITLE: Knowledge Structure & Cognitive Diagnosis

PRINCIPAL INVESTIGATOR: Albert Corbett and John Anderson
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R&T PROJECT CODE: 4421570 CONTRACT NO: N0001491J1597

Objective:
There are four objectives in this project, each directed at increasing our understanding of individual differences in skill acquisition: (a) to explore the usefulness of a variety of improvements to the knowledge tracing mechanism in the LISP Tutor; (b) to evaluate the hypothesis that knowledge tracing is not sensitive to important qualitative differences in the student's understanding of the domain; (c) to implement a revised tutor interface that makes it possible to observe planning processes more directly; and (d) to explore the relationship between subskills in programming.

Approach:
(a) An augmented knowledge tracing mechanism will be constructed and evaluated. This augmentation will track the surface contexts within which productions are fired. (b) Individual differences in retention will be explored by varying the intervals between a production's firing after criterion has been reached. The effects of this manipulation on firing time and accuracy will be examined. (c) The frequency, timing and access strategy of example references will be related to postest performance. (d) A revised tutor interface which admits variation in coding order and object size will be implemented. The relationship between coding order, object size, memory for examples, and posttest performance will be examined. This will permit the study of the transition from forward to backward chaining. (e) Transfer effects between code generation and code evaluation for specific algorithms will be studied.

Progress:
This grant is new in FY91.

TITLE: Conditional Dependence

PRINCIPAL INVESTIGATOR: Robert D. Gibbons
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R&T PROJECT CODE: 4421553 CONTRACT NO: N0001489J1104

Objective:
Recently, this investigator used an approximation technique based on the so-called Clark algorithm to obtain estimates of pattern probabilities which are robust to violations of conditional independence. This project is extending that work to new contexts. These include modelling performance on long tests (perhaps 50 items in length), on adaptive tests, on tests scored polychotomously, and on tests composed of several homogeneous subtests.

Approach:
Several techniques for estimating the residual covariances will be studied. These include: (a) using the sample tetrachoric correlations, (b) using the expected covariances from a higher dimensional solution, and (c) fitting specific patterned structures (e.g., first-order autocorrelation, block-diagonal, etc.). The viability of these approaches will be studied using simulated and real test data. Finally, a unidimensional polychotomous model for multidimensional data sets will be developed.

Progress:
Preliminary work on extending this approach to longer tests has focused on developing an EM solution and on implementing a ridge-like adjustment to stabilize a final Newton-Raphson step. The viability of these techniques is being examined using ACT data. An empirical comparison between the results of TESTFACT and Formula Score Theory is underway. And, the implementation of some of the heavy computations needed on a parallel board is under development.

Report:
Gibbons, R.D., Bock, R.D., & Hedeker, D. (1990) Approximating multivariate normal probabilities over rectangular regions. (Biometric Lab. Report 90-1). Chicago: Dept. of Psychiatry and Biometry, University of Illinois.

TITLE: Structural Assessment of Knowledge and Skill

PRINCIPAL INVESTIGATOR: Timothy E. Goldsmith and Peter Johnson
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R&T PROJECT CODE: 4421564 CONTRACT NO: N0001491J1368

Objective:
A substantial body of work has established that distinguishing properties of expert knowledge are structural. The objective of this work is to explore procedures for empirically obtaining and formally representing and comparing structural aspects of an individual's domain knowledge.

Approach:
In previous work the PI's developed and evaluated techniques based on the direct assessment of the relatedness of domain concepts and the scaling of those data using the PathFinder algorithm. This project will extend the previous work in several directions. First, it will explore alternatives to direct assessment of relatedness. Second, it will explore alternative definitions of idealized experts. Third, it will explore alternative measures of structural aspects and of quantifying structural similarity. Finally, it will explore alternative definitions of expertise.

Progress:
This grant is new in FY91.

TITLE: Structural Robustness and Local Dependence in Item Response Theory

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R&T PROJECT CODE: 4421560 CONTRACT NO: N0001491J1208

Objective:
This project seeks to extend Stout's essential independence framework in several directions. First, it seeks more complete trait-estimation and trait-distribution-estimation theories for tests which are only essentially unidimensional. Second, it seeks an item-response-function estimation theory. Third, it seeks necessary and sufficient conditions on observables for a test to be strictly unidimensional. Fourth, it will explore the theoretical relationships between classes of local dependence structures and multidimensionality.

Approach:
Initial work will (a) explore generalizations of the Kalback-Leibler information distance function as a vehicle for studying the optimality of item response functions in an essential-independence framework; (b) explore the theoretical connections between Sympson's polyweighting and efficient estimation of the dominant trait for essentially unidimensional tests; and, (c) empirically explore a novel approach to trait distribution estimation and compare it with extant procedures (especially Mislevy's).

Progress:
(a) Established the consistency of the maximum likelihood estimator of ability using a conditional-independence likelihood function when only essential independence holds, as test length increases. This robustness does not extend to variability of the conditional independence maximum likelihood estimator, however. (b) Established the asymptotic normality of the posterior distribution of ability under certain conditions. This result is a prelude to establishing the consistency of the posterior mean using a local independence likelihood under essential independence.

Report:
Clarke, B.S. & Junker, B.K. (1991) Inference from the product of marginals of a dependent likelihood. (Tech. Rep. 508, Department of Statistics, Carnegie-Mellon University).

TITLE: Expert Knowledge Structures and Their Role in Cognitive Task Performance.

PRINCIPAL INVESTIGATOR: Richard J. Koubek
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R&T PROJECT CODE: 4421558 CONTRACT NO: N0001490J1256

Objective:
This research is exploring differences in high-level cognitive skill based on individual differences in the knowledge representation of a complex cognitive domain. The main task is the development of a model of and a paradigm for externalizing the effect of an individual's acquired representation of domain knowledge on skilled performance. Additional studies will examine the implications of certain training variables and global cognitive abilities on the representation acquired.

Approach:
(a) An initial study involving students learning a word-processing task will explore the relationship between training variables, acquired representation, and performance as a function of task type. This study will also explore the feasibility and validity of an approach based on similarity judgments and multidimensional scaling for obtaining information about an individual's knowledge representation. (b) A second study will develop a taxonomy of expert knowledge representation types and will examine the suitability of each type for performing generic subtasks within a technical domain. In this study the efficacy of the similarity judgment-multidimensional scaling approach and an approach based on monitoring information requests during task performance to draw inferences about an individual's representation of domain knowledge will be compared. (c) A third study will examine the relationships between global cognitive abilities and features of an individual's acquired representation.

Progress:
Preliminary quantitative measures of knowledge representation have been developed for use in conjunction with multidimensional scaling techniques. Initial empirical results indicate that measured representation characteristics significantly influence performance on both complex and simple-repetitive cognitive tasks. Further development of knowledge representation measurement techniques is underway.

Report:
Koubek, R.J & Mountjoy, D.N. (1990) The role of training, individual differences, and knowledge representation in operator skill acquisition for manufacturing environments. In Karwowski, W. and Rahini, M. (Eds) Ergonomics of advanced manufacturing and Hybrid automated systems II. Amsterdam: Elsevier.

TITLE: New Tools for New Tests

PRINCIPAL INVESTIGATOR: Michael V. Levine
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R&T PROJECT CODE: 4421562 CONTRACT NO: N0001490J1958

Objective:
Two general approaches for modelling performance on complex cognitive tasks are being developed: maximum-likelihood (MFS) and algebraic (AFS) formula-score theories. MFS will be a tool for checking hypotheses about information processing on complex tasks. Abstract manifolds from AFS will be a vehicle for obtaining representations of performance. Computer algorithms for both approaches are being refined.

Approach:
A variety of constraints suggested by cognitive process models in specific task domains are being explored to reduce the estimation space of item response functions. These include smoothness constraints, monotonicity constraints, and explicit functional form constraints in task domains with sufficiently strong psychological theory. Initial work on AFS will explore low-dimensional parameterizations of test manifolds, improvements to numerical algorithms, and exploration of the viability of the AFS approach for specific modelling applications.

Progress:
It has been shown that manifolds for the most commonly used multidimensional test models, the "cylindrical models" have special properties that can be experimentally tested. Additionally, an algorithm for solving the functional equations for two-dimensional cylindrical models has been found. As a result the essentially unique item response functions from cylindrical models can now be computed.

TITLE: Polychotomous Measurement for ASVAB

PRINCIPAL INVESTIGATOR: Michael V. Levine and Fritz Drasgow
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R&T PROJECT CODE: 4428020 CONTRACT NO: N0001489K0059

Objective:
This research is integrating, contrasting, and evaluating extant polychotomous models. Parametric models under study include Bock's nominal model, Samejima's model, and Thissen's model. Nonparametric models include Levine's formula score theories, Samejima's conditional PDF methods, and Sympson's polyscore method.

Approach:
There are three lines of attack: refinement of the methods, conceptual integration, and empirical comparison with simulated and real test data.

Progress:
Experiments with Samejima's conditional PDF method have been carried out to determine sensitivity to initial function estimate and rate of convergence. The most probable cause for the poor model fit of SAT data appears to be the instructions regarding penalty for incorrect answers. Methods used for MFS have been applied to the PDF method to study conditions for convergence. Methods for judging goodness of model fit for model based simulation data have been developed. A model free method for measuring goodness of fit to actual data has been formulated and is now being developed.

Report:
Levine, M.V., Drasgow, F., Williams, B., McCusker, C., & Thomasson, G. L. (1990) Distinguishing item response models. (Tech. Rep. 90-1) Champaign, IL: Model-based Measurement Laboratory, University of Illinois.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Toward a Test Theory for Assessing Student Understanding

PRINCIPAL INVESTIGATOR: Robert J. Mislevy
Educational Testing Service
(609) 734-1271

R&T PROJECT CODE: 4421573 CONTRACT NO:

Objective:
The objectives of this work are to develop statistical methodologies for updating probabilities in an inference network and to explore the viability of these methodologies for solving the model inference problem in diagnostic testing. Work will investigate the effects of model misspecification, will explore alternative models which reduce the negative impacts, will extend the models to handle learning, and will develop techniques for identifying persons with unexpected patterns of behavior.

Approach:
Initial work will study the performance of the MUNIN algorithm for updating probabilities in an inference network with a variety of simulated and actual-performance data sets. The simulation studies will examine the effects of model violations, such as conditional independence. Work with actual-performance data will examine the effects of various sorts of model re-specification, such as variations in grain size. Other work will extend optimal appropriateness measurement to inference network models and will develop techniques for handling learning.

Progress:
This grant is new in FY91.

TITLE: Prediction of Performance in Occupations Requiring High Levels of Adaptability.

PRINCIPAL INVESTIGATOR: Michael D. Mumford and Edwin Fleishman
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R&T PROJECT CODE: 4428030 CONTRACT NO: N0001491J1435

Objective:
This work will extend, refine and validate the PI's theory of the relationship between performance on background data items and performance in occupations requiring high levels of adaptability. The objective is to provide a sound theoretical basis for systematic development of background data instruments.

Approach:
First, an initial set of constructs thought to affect adaptability will be elaborated. Second, background data items will be formulated to mark the prior expression of these constructs in an adequate sample of situations. Third, these items will be used to formulate rational scales for measuring each construct. Fourth, reliability and validity of these measures will be examined.

Progress:
This grant is new in FY91.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Fitting Symbolic Parameter Cognitive Models

PRINCIPAL INVESTIGATOR: Allen Newell and T. Polk
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R&T PROJECT CODE: 4421567 CONTRACT NO: N0001491J1527
4421568 N0001491J1529

Objective:
Many of the cognitive models in Psychology can be viewed as subject-general models with parameters that take discrete symbolic values. Assigning values to the parameters creates a runnable model that simulates the subjects performance to some degree of accuracy. The objective of this project is to create a computational and statistical technology for fitting symbolically parameterized cognitive models to human data and for doing the analyses of these models for significance and sensitivity.

Approach:
The cornerstone of this project is the ASPM algorithm which identifies the sets of parameter values which fit the largest number of responses in an examinee's data set. In this project, ASPM will be refined, extended and evaluated.

Progress:
These grants are new in FY91.

TITLE: Multidimensional Item Response Theory Applied to Practical Testing Problems

PRINCIPAL INVESTIGATOR: Mark D. Reckase
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R&T PROJECT CODE: 4421556 CONTRACT NO: N0001489J1908

Objective:
Develop a practical methodology for analyzing test items that require more than one cognitive ability to achieve a correct response. Issues under study include: (a) estimating item parameters, (b) linking the scales of item parameter estimates from different analyses, (c) equating scales of vector ability parameter estimates and of composites of elements of the ability vectors, (d) technical specification for tests that measure multiple abilities, and (e) multidimensional adaptive testing.

Approach:
(a) Estimates of standard errors and of statistical bias will be used to determine the optimal characteristics of samples used to obtain item parameter estimates. (b) Marginal maximum likelihood procedures will be evaluated for parameter estimation. (c) The Stocking and Lord procedure will be explored as a model for linking the scales of parameter estimates. (d) Equating methodologies will be evaluated with empirical studies on ACT Assessment data.

Progress:
(a) Methods have been developed to gauge the parallelism of tests that measure multiple cognitive dimensions. (b) New procedures have been developed to assess the reliability of tests that measure multiple dimensions.

Report:
Reckase, M.D. (1989) Adaptive testing: The evolution of a good idea. Educational Measurement Issues and Practice, 8, 11-16.

TITLE: Further Advancement of Latent Trait Theory and Challenge to the Multiphase Response

PRINCIPAL INVESTIGATOR: Fumiko Samejima
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R&T PROJECT CODE: 4421549 CONTRACT NO: N0001490J1456

Objective:
The objective of this work is to extend the theoretical foundations of latent-trait theory. This includes: (a) improvements to modelling techniques, (b) the development of a framework for studying the validity of items and tests as a function of ability, (c) the development of efficient multidimensional modelling techniques, and (d) the extension of latent-trait theory to modelling the details of performance on tasks involving sequences of behavior.

Approach:
(a) The PI's Differential Weight Procedure will be refined and tested. (b) The usefulness of approximations derived from results for multidimensional models of continuous responses will be examined. (c) A variety of ways to conceptualize an item's (and a test's) local validity will be examined. And, (d) applications to modeling a student's understanding of digital circuits will be explored.

Progress:
A new approach for modeling the operating characteristics of discrete responses to test items has been developed (i.e., the differential weight procedure). Initial indications are that it is a substantial improvement over the familiar simple-sum procedure when the response functions are steep and the data are sparse.

Report:
Samejima, F. (1990) Content-based observation of informative distractors and efficiency of ability estimation. Tech. Rep. 90-1 Knoxville, TN: University of Tennessee, Psychology Department.

TITLE: Foundations of Multidimensional Item Response Theory.

PRINCIPAL INVESTIGATOR: William F. Stout
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Department of Statistics
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R&T PROJECT CODE: 4421548 CONTRACT NO: N0001490J1940

Objective:
This work is further developing the foundations of item response theory for multidimensional data sets. This includes: (a) exploration of the theoretical relationship between a conditional-association notion of dimensionality and Stout's notion of the essential dimensionality of a data set, (b) exploration of the implications of the Suppes and Zanotti Common Causes Theorem for multidimensional IRT modelling, (c) development of a framework for studying issues of test bias based upon the notion of the essential dimensionality of a test, and (d) exploration of alternative dependence structures for multidimensional modelling.

Approach:
(a) Stout's notion of the essential dimensionality of a data set is being refined and extended, and the relationship between it and Holland's notion of conditional association is being studied. (b) The notion of test bias is being cast within the essential dimensionality framework in order to gauge when group differences are likely to be troublesome. (c) New notions of the reliability of a test are being explored. And, (d) models based upon sequential dependence structures are being examined.

Progress:
Substantial progress has been made on three issues: characterization and assessment of the essential dimensionality of a test, characterization and assessment of test bias, and foundational work on the estimation of ability.

Report:
Stout, W. (1990) A new item response theory modelling approach with applications to unidimensional assessment ability estimation. Psychometrika, 55, p. 293-326.

TITLE: Improved Scoring for Tests and Criteria

PRINCIPAL INVESTIGATOR: J. B. Sympson
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(619) 553-7610

R&T PROJECT CODE: 4421554 CONTRACT NO:

Objective:
Develop new item-selection and performance-modelling techniques which have the potential for increasing the reliability and validity of tests and criteria. Although emphasis will be given to modelling multicategory data, attention will also be given to exploiting information in response times.

Approach:
First, Sympson's polyweighting procedure will be compared to number-correct and IRT-based scoring using both simulation and Navy test data. Second, Sympson's model 8 will be adapted for use in modelling dichotomous item responses. Third, a new procedure for gauging IRT model goodness-of-fit will be developed. Fourth, analyses will be conducted to determine whether test scores that are functions of both accuracy of response and speed of response can increase test reliability and validity. Finally, work aimed at improving the scaling of criterion measures will explore the validity of applying polychotomous scoring to these measures.

Progress:
(a) An empirical comparison of polyweighting, number-correct scoring, and IRT scoring has been completed. (b) A portable computer program for linear polychotomous item analysis was developed. (c) A portable computer program for fitting a 5-parameter dichotomous IRT model was developed. (d) A new IRT model goodness-of-fit procedure was developed and applied to Navy data. (e) A new instrument for collecting polychotomous job-performance data for the Navy EM rating was developed. (f) A comprehensive literature review is nearing completion.

Report:
Sympson, J.B. (1990) Improved scoring for personnel tests. In Proceedings of the International Personnel Management Association Assessment Council 1990 Conference on Personel measurement.

TITLE: Advancement of the Theory of IRT-Based Error Diagnostic Testing.

PRINCIPAL INVESTIGATOR: Kikumi K. Tatsuoka
Educational Testing Service
Model-based Measurement Research Group
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R&T PROJECT CODE: 4421559 CONTRACT NO: N0001490J1307

Objective:
The objective of this work is to extend the Rule Space approach to diagnostic testing in three important areas: (a) a coherent approach to test item construction/selection/evaluation will be developed; (b) a more powerful approach to classifying response patterns will be sought; and (c) techniques for modelling "bug migrations" will be explored.

Approach:
(a) The investigators' approach to the item construction/selection issue involves constructing stochastic models of item subtask performance. Their initial approach views item subtasks as known entities. (b) The focus of attention for increasing the power of classification procedures will be on methods which avoid the multivariate Normality assumption employed in discriminant analysis. Methods such as kernel density estimation and the k-nearest-neighbor method will be explored initially. (c) Work on identifying and modelling "bug migrations" will employ combinatorial analyses of response patterns to detect phase changes.

Progress:
(a) A detailed empirical validation of rule-space diagnoses in the fraction-arithmetic domain has been completed. Results indicated that rule space is an effective tool for routing students to remedial instruction. (b) Results of a second study confirmed the robustness of the rule-space classification scheme to violations of the normality assumption.

Report:
Tatsuoka, K.K. (1990) Toward an integration of item response theory and cognitive error diagnosis. In Frederiksen, N. et al. (eds) Diagnostic monitoring of skill and knowledge acquisition. Hillsdale, NJ: Erlbaum.

TITLE: On-Line Assessment of Individual Expertise

PRINCIPAL INVESTIGATOR: Kurt VanLehn, Micheline T.H. Chi, and Robert Glaser
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Learning Research & Development Center
(412) 268-2781

R&T PROJECT CODE: 4421566 CONTRACT NO: N0001491J1532

Objective:
This work is exploring innovative methodologies for monitoring a student's evolving understanding of concepts and problem-solving skill in Physics. The idea is to develop a methodology for constructing theoretically well-grounded models of a student on the basis of data collected on line as the student is engaged in studying examples, solving quantitative and qualitative problems, planning a basic approach to a problem, and classifying problems.

Approach:
(a) A schema-based model of performance in Physics is being extended and refined. (b) The viability of novel indicators of schema attainment is being examined. Many of these data sources are suggested by laboratory experiments exhibiting performance differences as a function of expertise; others are suggested by experiments identifying learning skills which distinguish good and poor physics students. (c) A computational model of the acquisition of Physics skill is being refined. (d) Standard data analysis techniques are being supplemented by techniques from the AI and machine-learning literatures. In particular, techniques for plan recognition are being extended.

Progress:
This grant is new in FY91.

TITLE: The Implications of Multidimensionality for Item Response Theory Applications

PRINCIPAL INVESTIGATOR: Ming-mei Wang
Educational Testing Service
Research Department
(609) 734-1933

R&T PROJECT CODE: 4421561 CONTRACT NO: N0001490J1970

Objective:
This work has three main objectives: (a) to examine the relationship between estimated multidimensional models and their estimated unidimensional counterparts; (b) to develop methods for empirically assessing the "strength" of multidimensionality in terms of the conditional dependence among items; and (c) to provide a framework for evaluating the effectiveness of unidimensional versus multidimensional modelling in testing applications.

Approach:
(a) A detailed analysis of the model-based explanations for differential item functioning is being constructed with emphasis on the issue of multidimensionality. (b) The effects of multidimensionality on test equating and on the interpretability of equated scores are being addressed in terms of characteristics of equating samples. (c) The relationship between characteristics of a multidimensional item pool and the efficiency of unidimensional adaptive testing is being studied. And, (d) an effective item selection strategy is being developed with the aid of estimated multidimensional item response functions.

Progress:
An analytical framework based on the linearity of item logit scores for the usual compensatory logistic item response model was defined. Within this framework algebraic relationships between unidimensional estimates and true multidimensional parameters were derived. The implications of this relationship for various testing applications have been discussed.

Report:
Wang, M.M. (1990) Unidimensional versus multidimensional modelling for test development. (Tech. Rep.) Iowa City, IA: University of Iowa.

TITLE: Strategies of Skill Acquisition: A Mixture Model Approach to Measurement in the Context of Intelligent Tutoring

PRINCIPAL INVESTIGATOR: Mark R. Wilson and Peter Pirolli
University of California, Berkeley
School of Education
(415) 642-7966

R&T PROJECT CODE: 4421569 CONTRACT NO: N0001491J1523

Objective:
The objective of this project is to explore techniques for drawing inferences about a student's study strategies and his/her understanding of a domain in the context of intelligent tutoring. Three task domains and tutors are under study: the LISP tutor (LISP programming language), the Bridge tutor (PASCAL programming language), and the Smithtown tutor (discovery of economic principles).

Approach:
Initial work is focusing on refining mixture models as a vehicle for drawing inferences about a student's learning and problem-solving strategies. In this phase, secondary analyses of existing data sets are being employed. Subsequent work will involve refinement of aspects of the cognitive models of domain knowledge, the collection of supplementary data (e.g., on a student's approach to example studying), on the exploration of inference network techniques for reaching conclusions about a student's domain knowledge, and on validation of the model-inference techniques.

Progress:
This grant is new in FY91.

PERCEPTUAL SCIENCE

VISION AND VISUAL ATTENTION

TITLE: The Neural Basis of Visual Segmentation and Recognition

PRINCIPAL INVESTIGATOR: Gordon Baylis
University of California, San Diego
Department of Psychology
(619) 534-3000

R&T PROJECT CODE: 4424269 CONTRACT NO: N0001491J1735

Objective:
(1) Perform psychophysical and single unit studies to gain a deeper understanding of mechanisms underlying: (a) the extraction of edges from multiple cues; (b) how conflicting information is dealt with; (c) how edges are classified as extrinsic and intrinsic; and (d) how the description of extrinsic edges interacts with object segmentation. (2) Carry out psychophysical and physiological studies of the mechanisms and algorithms underlying the extraction of information on the third dimension. (3) Develop neural network models of object segmentation and recognition based on experimental evidence. Attempt to develop insights into the computational significance of the architecture of the inferior temporal cortex by analysis of model architectures.

Approach:
Techniques of psychophysics, modeling, and single unit recording in areas V4 and IT will be closely linked to produce biologically feasible models of object segmentation and three dimensional object recognition in primate visual system.

Progress:
This grant in new in FY91.

TITLE: Studies of Contour and Surface Segmentation in Monkey Striate Cortex Using Voltage Sensitive Dyes

PRINCIPAL INVESTIGATOR: Gary G. Blasdel
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Department of Neurobiology
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R&T PROJECT CODE: 442g005 CONTRACT NO: N0001489J1953

Objective:
The objectives of this research are to: (1) determine the extent to which striate cortex neurons are sensitive to the distinction between contour edges and surface edges; (2) to explore the anatomical and topological organization of striate cortex cell groups categorized on this basis.

Approach:
Extracellular single unit recordings in monkey striate cortex will be used to determine response selectivity to surface and contour edges in response to a variety of visual stimuli. Optical imaging with voltage-sensitive dyes will be used to map patterns of cortical activity in response to visual stimuli optimized for distinguishing contour-edge and surface-edge sensitive regions.

Progress:
Single unit recording studies during the past year reveal (a) that 90% of the cells in the monkey striate cortex are designed to detect contours (edges) rather than surfaces, (b) cells designed to detect surfaces are grouped in clusters lying close to orientation fractures within the columnar organization of the cortex, and (c) prolonged anaesthesia causes reductions in selectivity for single edges, producing a state in which most cells respond as surface detectors.

Report:
Blasdel, G. (1990) Differential imaging of ocular dominance and orientation selectivity in monkey striate cortex. Submitted to the Journal of Neuroscience.

TITLE: Neurophysiological Implementation of a Scheme for Visual Selective Attention

PRINCIPAL INVESTIGATOR: John Duncan
Medical Research Council
Applied Psychology Unit
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R&T PROJECT CODE: 4424266 CONTRACT NO: N0001491J1347

Objective:
The objective is to address two theoretically significant issues regarding the mechanistic basis of visual selective attention: (1) to what extent, under what conditions, and at what anatomical location(s) are attentional templates (a flexible advance description of the visual information needed to perform a task) employed in attention-demanding tasks such as match-to-sample? and (2) Does attentional processing of a non-spatial nature exhibit the same pattern of neural modulation as does spatial selective attention?

Approach:
Single unit recording techniques will be used to examine patterns of activity in a variety of extrastriate and temporal cortical regions during attention demanding tasks in which alert monkeys are presented with multiple simultaneous stimuli.

Progress:
This grant is new in FY91.

TITLE: Visual Perception of Depth-from Occlusion: A Neural Network Model

PRINCIPAL INVESTIGATOR: Leif H. Finkel
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Department of Bioengineering
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R&T PROJECT CODE: 4424255 CONTRACT NO: N0001490J1864

Objective:
The objective is to uncover how the visual system perceives depth from occlusion--the situation in which one object partially blocks the view of a more distant object--and to incorporate this understanding into the design of a neural network model capable of emulating the depth perception performance of biological visual systems.

Approach:
The research approach consists of (1) developing and implementing a model of occlusion discrimination in a neural network system, (2) using this model to investigate mechanisms of integration of depth information, and (3) writing a computer simulation program to carry out a formal evaluation of the computability of the neural network model.

Progress:
Several preparatory projects are underway which are aimed at developing a biologically-based model of how the visual cortex extracts depth from occlusion. The major effort is in writing software for a large scale neural network simulator which allows simulation of networks containing hundreds of thousands of cells.

Report:
Finkel, L.H. (1990) The construction of perception, in J. Crary (Ed.), Zone, Vol. 6, Urzone:New York (In Press).

TITLE: Core Support for the Committee on Vision

PRINCIPAL INVESTIGATOR: Pamela Flattau
National Academy of Sciences
(202) 334-2565

R&T PROJECT CODE: 4426125 CONTRACT NO: N0001487K0345

Objective:
Provide information on current and anticipated problems relevant to Navy and other federal agencies in the areas of vision, visual standards, and hazards to vision.

Approach:
Working groups will be formed to address specific issues identified by a sponsor. Each group will be made up of leading experts in scientific fields relevant and specific to the problem at hand, and will produce a document responsive to problem solution.

Progress:
The Vision Committee continues to provide conferences and reports relevant to the problems of visual human factors technology in the Navy and the DoD in general.

TITLE: Computational and Psychophysical Study of Human Vision Using Neural Networks

PRINCIPAL INVESTIGATOR: Donald A. Glaser
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R&T PROJECT CODE: 4424243 CONTRACT NO: N0001490J1251

Objective:
The objective is to carry out empirical investigations to evaluate and modify current computational models of processes by which information about the physical properties of the external environment is extracted by the human visual system. Of primary interest are the investigation of detection and identification of moving objects in noisy environments, the role of global (non-local) processes in the perception of three dimensionality, the perception of flow patterns and textures, and the processes by which detectable lines and their intersections within images are labeled or assigned roles in image interpretation.

Approach:
The approach is interdisciplinary, combining empirical investigation at the level of visual psychophysics and computational modeling. Preliminary theoretical developments are used to guide the specification of empirical questions, and the resultant findings are used to evaluate and extend theoretical formulation.

Progress:
Experiments revealed that depth perception of simple dots and lines in the center of the field of view is grossly altered by other dots and lines almost anywhere in the whole field of view. In addition, it was found that the perception of speed in central display patterns is altered by other dots blinking on and off in the same scene. These results impose significant constraints on the kinds of neural net or other models appropriate for characterizing human vision.

Report:
Bowne, S.F., McKee, S.P., and Glaser, D.A. (1989) Motion interference in speed discrimination. Journal of the Optical Society of America, 6, 1112-1121.

TITLE: Using Time-to-Collision to Recover 3-D Motion for Navigation and Manipulation

PRINCIPAL INVESTIGATOR: Ellen Hildreth
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R&T PROJECT CODE: 400x053 CONTRACT NO: N0001488K0607

Objective:
To establish the computational and psychophysical bases for design of networks that have the capacity to compute quickly and accurately the structure and relative motions of environmental objects with which an artificial system may physically interact during the course of navigation and object manipulation.

Approach:
Estimates of the time-to-collision with an approaching surface will be used to investigate the recovery of 3-D trajectory of moving targets. The psychophysical findings will be employed as the basis for design of computational models of visually-guided navigation and object manipulation.

Progress:
An algorithm has been developed that reconstructs a 3-D trajectory from simple measurements of the position, velocity and rate of expansion of image features, and then derives global parameters for the trajectory (that is, initial 3-D position of the object and velocities through space).

Report:
Hildreth, E. (1990) Computational studies of visual motion analysis. In: Models of Visual Perception: From Natural to Artificial, M. Imbert (ed.), Oxford University Press.

TITLE: Electrophysiological Studies of Visual Selective Attention and Resource Allocation

PRINCIPAL INVESTIGATOR: Steven A. Hillyard
University of California, San Diego
Department of Neurosciences
(619) 452-3797

R&T PROJECT CODE: 4426556 CONTRACT NO: N0001489J1806

Objective:
To clarify mechanisms of visual-spatial selective attention in humans, both at the level of perceptual processing and at the level of the underlying brain physiology. The focus will be on the effectiveness of different advance cueing procedures for orienting attention to regions of a visual display.

Approach:
The indices of attentional orienting to be studied are facilitation of reaction times and enhanced event-related potentials (ERPs) to stimuli at attended locations. The proposed methods will eliminate confounds that have clouded the interpretation of previous studies.

Progress:
Reaction times for completion of a visual search task were compared for normal subjects and patients who have undergone surgical trans-section of the corpus callosum. Bilateral stimulus arrays were scanned faster by "split brain" subjects than by normal subjects, suggesting that each of the surgically separated hemispheres generates an independent focus of attention.

Report:
Luck, S., Hillyard, S. Mangun, G., and Gazzaniga, M. (1989). Independent hemispheric attentional systems mediate visual search in split brain patients. Nature, 342, 543-45.

TITLE: Formal and Psychophysical Investigations of Vision: Image Motion and Occluding Contours

PRINCIPAL INVESTIGATOR: Donald D. Hoffman
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Department of Cognitive Sciences
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R&T PROJECT CODE: 4424219 CONTRACT NO: N0001488K0354

Objective:
The objective of the proposed research is to develop and evaluate both empirically and computationally a formal theory of the mechanisms by which object shape can be inferred from motion and contour occlusion. An additional objective is to implement this theory in neurally plausible computer algorithms.

Approach:
The proposed investigation will consist of three integrated thrusts: (1) the development of formal theories of shape-from-motion and shape from occluding contours, (2) the testing of these theories by psychophysical experiments, and (3) the implementation of these theories in neurally plausible computer algorithms.

Progress:
Lebesque logic, by which one can define when one probability space implies another, is currently being explored as a tool for characterizing the probabilistic inferencing underlying much of visual processing. Particular emphasis is on probabilistic inferences associated with (a) the poisson distributions of photons falling at the retina, (b) the multistable interpretation of 3D structure arising from motion and shading, and (c) the probabilistic recognition and identification of 3D objects.

Report:
Bennett, B.M., Hoffman, D.D., Nicola, J.E., Prakash, C. (1989) Structure from two orthographic views of rigid motion. Journal of the Optical Society of America, A.6, 1052-1069.

TITLE: Analog Neuronal Networks for Early Vision

PRINCIPAL INVESTIGATOR: Christof Koch
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R&T PROJECT CODE: 442g006 CONTRACT NO: N0001491J1174

Objective:
Objective is to develop theoretical models of computation for early visual processes toward analog VLSI chips for use in robotic vision systems.

Approach:
Approach is to simulate analog algorithms for vision on a hypercube computer in two stages; first as independent, then as integrated processes. Explore design possibilities for silicon implementation.

Progress:
A 20x20 pixel chip was designed with circuitry that performs surface segmentation and smoothing of visual input. The analog VLSI circuit implements a non-linear resistive network with "fuses" that detect discontinuities and limit the smoothing operation. A variety of resistive networks find edges, compute depth and optical flow in the presence of discontinuities. These circuits are sufficiently robust to allow edge following and tracking when mounted on toy cars in laboratory environments.

Report:
Harris, J.G., Koch, C., and Luo, J. (1990) A two-dimensional analog VLSI circuit for detecting discontinuities in early vision. Science, 248, 1209-1211.

TITLE: Control of the Minds Eye: The Dynamics of the Distribution of Visual Attention

PRINCIPAL INVESTIGATOR: Arthur F. Kramer
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R&T PROJECT CODE: 4424228 CONTRACT NO: N0001489J1493

Objective:
The objective is to develop an empirically based model of visual selective attention which describes, at multiple levels of representation, the control of the allocation of attention in visual space.

Approach:
Interference in response speed and accuracy produced by visual distractors will be used as an index to investigate a number of critical issues related to the computational properties of visual-spatial attention. Included among these issues are the following: (1) the minimal visual angle or focus of attention in which all events must be processed; (2) the information processing level(s) at which noise stimuli of various types operate to degrade performance; and (3) the effects of training on the ability of performers to adaptively filter unwanted components of a visual scene.

Progress:
A finding of major theoretical significance was obtained during the past year of funding. Specifically, it was established that contrary to established view, visual attention is distributed in an object-based representational framework rather than on the basis of visual space. In addition it was determined that the magnitude of the object-based attentional effects is strongly influenced by both the structure of the display and subjects processing strategies.

Report:
Kramer, A.F., Strayer, D.L. & Buckley, J. (1990). Development and transfer of automatic processing. Journal of Experimental Psychology: Human Perception and Performance, 16, 505-522.

TITLE: Investigation of Spread of Attention in the Visual Field

PRINCIPAL INVESTIGATOR: David La Berge
University of California, Irvine
Department of Cognitive Sciences
(714) 856-6802

R&T PROJECT CODE: 4424208 CONTRACT NO: N0001490J1447

Objective:
The objective is to test and elaborate the PI's gradient theory of visual-spatial attention. Evaluation of the theory will be based on empirical research and computer simulation.

Approach:
An extensive series of experiments will be carried out to analyze the 'width of attentional focus' effect, on which the PI's theory of attention is based, to explore methods to produce and sustain a focus of a given size, and to determine ways in which the focus-width effect can be exploited to optimize human performance in tasks involving object recognition.

Progress:
Psychophysical and theoretical studies have led to the development of a mathematical model of attention spread and to a PET scan experiment which strongly suggests that a mechanism of selective attention is located in the pulvinar nucleus of the thalamus. A neural network model based on the known circuitry of the thalamus has been developed and computer simulated, yielding results similar to those obtained with human subjects in selective attention tasks.

Report:
LaBerge, D. (1990) Thalamic and cortical mechanisms of attention suggested by recent positron emission tomographic experiments. Journal of Cognitive Neuroscience, 2, 124-131.

TITLE: Processing Information in the Cerebral Cortex

PRINCIPAL INVESTIGATOR: John H. Maunsell
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Strong School of Medicine and Dentistry
(716) 275-2076

R&T PROJECT CODE: 4424242 CONTRACT NO: N0001490J1070

Objective:
The objectives of this work are: (1) to determine if neurons that are most active when the animal searches for a specific visual stimulus also respond selectively during search for a specific haptic stimulus; (2) to determine whether individual neurons can signal task-specific information for more than one task; (3) to determine effects of training on task-specific responses of cortical neurons.

Approach:
Recordings of single unit activity in cortical area V4 of alert macaque monkeys will be obtained during match-to sample-tasks in which the sample and the choice are either visual or tactile stimuli.

Progress:
Work has continued on symbolic representation by neurons in the primate visual cortex. Work in area V4 has been completed, and reveals that as many as 20% of the neurons convey signals that are symbolic, in the sense that their activity can dissociated from any particular sensory input or motor output. A corresponding study of area V1 reveals no evidence for symbolic representation. A new project has been initiated to explore representations in extrastriate cortical areas that are involved in motion processing.

Report:
Maunsell, J.H.R., Sclar, G., Nealey, T.A. and Depriest, D.D. (In Press) Symbolic representation by neurons in the extrastriate visual cortex of the macaque monkey. Journal of Neuroscience.

TITLE: Visual Integration and Recognition

PRINCIPAL INVESTIGATOR: Tomaso A. Poggio
Massachusetts Institute of Technology
Center for Biological Information Processing
(617) 253-5230

R&T PROJECT CODE: 442g002 CONTRACT NO: N0001491J1270

Objective:
Objective is to specify biologically plausible implementation models for visual cue integration and object recognition.

Approach:
Approach is interdisciplinary collaboration in computational modeling and psychophysical experimentation. Theoretical and computational studies will model the information processing tasks involved in visual integration and recognition. Algorithms will be developed and tested on a parallel supercomputer. Computational work will guide design of experiments in human perception.

Progress:
A new theory of object recognition has been developed based on the idea that learning from examples is equivalent to approximating a multivariate function. It assumes that some brain modules are designed to perform function approximation and represent objects as look-up tables. Object recognition is a process of accessing tables containing appropriate descriptions. Preliminary experiments have been conducted on recognition of novel views of objects based on previously learned prototypical views.

Report:
Poggio, T. and Edelman, S. (1990) A network that learns to recognize three-dimensional objects. Nature, 343: 263-266.

TITLE: Functions of Identified Neural Areas in Selective Attention

PRINCIPAL INVESTIGATOR: Michael I. Posner
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Department of Psychology
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R&T PROJECT CODE: 4424233 CONTRACT NO: N0001489J3013

Objective:
The objective is to understand general principles underlying the regulation of data processing in the brain by the attentional system. Two major ideas emerging from the PI's earlier work are to be evaluated: (1) the attentional system is functionally and anatomically distinct from the data collection and execution systems on which it operates; and (2) the attentional system is defined as a set of interconnected posterior and anterior brain areas that taken together select information for focal processing.

Approach:
The approach entails the use of both behavioral (reaction time) and neuroscientific (evoked potential) techniques to investigate the relation between attention and data collection systems in the human brain. Evoked potential measures will be used to track patterns of attentional activation progressing from anterior (midline anterior cingulate to supplementary motor area) to posterior (parietal and temporal) attentional structures following the cuing of likely target locations.

Progress:
Three networks have been defined that are important components of the attention system of the human brain. These are the posterior visual spatial attention system, the anterior system responsive to target detection in all domains, and the vigilance system. The development of the posterior system has been examined in ontogeny. ERP methods have been developed for tracing the time course of the interaction of the posterior attention system with visual word forms, examining both the source of the attention effect and its site of activity. The vigilence system has been shown to have asymmetric influences on orienting.

Report:
Posner, M.I. & Petersen, S. (1990) Attention systems of the human brain. Annual Review of Neuroscience, 13, 25-42.

TITLE: Neural Models of Depth Perception in Visual Cortex

PRINCIPAL INVESTIGATOR: Terrence J. Sejnowski
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(619) 453-4100

R&T PROJECT CODE: 4424258 CONTRACT NO: N0001491J1141

Objective:
Physiological studies have shown that binocular disparity is encoded at each spatial location by the pattern of activity in a population of disparity-selective neurons. The objective of this theoretical study is to incorporate this type of disparity representation into a neural model of binocular depth perception.

Approach:
A number of computational models will be developed using recently introduced techniques for training recurrent neural networks. Of special focus is how horizontal disparity is extracted from pairs of images, how egocentric depth is computed from stereopsis and other sources of information such as eye vergence, and how different sensory cues can be fused to form an accurate representation of depth.

Progress:
This grant is new in FY91.

TITLE: The Role of Attention in Visual Processing

PRINCIPAL INVESTIGATOR: Gordon L. Shulman
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R&T PROJECT CODE: 4424229 CONTRACT NO: N0001489J1426

Objective:
The objective is identify the anatomical locus of a variety of attentional effects in vision which have not been investigated on a systematic basis. Both spatial and non-spatial attentional effects will be studied, using sensory adaptation as the vehicle for identifying attentional influences.

Approach:
Sensory adaptation and sensory learning effects will be investigated in the presence and absence of focused attention. Since the anatomical locus of the adaptation effects studied have been established, it is possible by this means to isolate the anatomical locus of attentional effects in the visual information processing sequence.

Progress:
Several experiments have established that 3-D motion aftereffects are modulated by attention. A quantitative model describing the effect of attention on motion aftereffects was developed, and subsequently verified experimentally. Most recently, the role of attention in aftereffects has been extended experimentally to perspective aftereffects.

Report:
Corbetta, M., Miezin, F., Dobmeyer, S. Shulman, G. and Peterson, S. (1990) Attentional modulation of neural processing of shape, color, and velocity in humans. Science, 248, 1556-1559.

TITLE: Visual Attention and Short Term Memory

PRINCIPAL INVESTIGATOR: George Sperling
New York University
Psychology Department
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R&T PROJECT CODE: 4424221 CONTRACT NO: N0001488K0569

Objective:
The objective of the proposed project is to develop formal quantitative descriptions of the mechanisms by which attentional modulation and control structures determine the perception of visual events, and to incorporate these descriptions into a theoretical treatment of human information processing and the sources of its limitations.

Approach:
The proposed project incorporates both psychophysical and computational analyses to generate the empirical basis for and computational evaluation of a formal theory of the role of attention in the analysis of visual sensory input.

Progress:
A general mathematical theory of visual attention was completed and applied to the four major paradigms used to study attention. The theory depicts attention as consisting of a sequence of separable episodes: each episode is defined by its spatial function and the transitions are characterized by a separable temporal function. Experimental work revealed the theory can account quantitatively for recall strategies in iconic memory.

Report:
Sperling, G. & Weichselgartner, E. (1990) Episodic theory of the dynamics of spatial attention. Submitted to Psychological Review.

TITLE: Constructing 3D Surface Descriptions

PRINCIPAL INVESTIGATOR: Kent A. Stevens
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Department of Computer Science
(503) 686-4430

R&T PROJECT CODE: 4424245 CONTRACT NO: N0001490J1472

Objective:
The objective is to develop a comprehensive theory of 3-D form perception based on the assumption of two independent representation systems for distance information: (a) for absolute distance, indicated by binocular disparity, and (b) for local object-referenced depth relations.

Approach:
Theoretical analysis, computational modeling, and psychophysical experimentation are utilized to determine the nature of surface topographic features, their interactions, and how the perception of 3D form arises in human vision from those features.

Progress:
Investigation is underway on how spatially separated and superimposed monocular and stereo cues to surface curvature are combined. Notable among the early findings are that subjects exhibit strong learning effects in trying to resolve inconsistent cues as to depth and that subjects differ considerably in the relative emphasis they place on mono versus stereo cues when these are placed in conflict. Subjects not only start from different set points but then evolve to different extents in the way they interpret stimuli after a few hours of observation.

Report:
Brookes, A. & Stevens, K.A. (In Press) Binocular depth from surfaces vs volumes, Journal of Experimental Psychology: Human Perception and performance.

TITLE: Visual Perception and Cognition of Smoothly Curved Surfaces

PRINCIPAL INVESTIGATOR: James T. Todd
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Department of Psychology
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R&T PROJECT CODE: 4424241 CONTRACT NO: N0001490F0003

Objective:
During the past decade, there have been numerous algorithms proposed in the literature for computing an object's 3D form from a sequence of projected images taken from different perspectives. The objective here is to identify the key assumptions underlying these alternative algorithms and to empirically examine the relative psychophysical validity of these assumptions.

Approach:
The approach is to determine the psychophysical implications of competing models of the process by which 3D form is computed from the 2D image projected to the retinal surface, and to subject these implications to rigorous empirical test.

Progress:
Progress has been made along two fronts. First, software has been developed for the new image processing system acquired on the grant. Consequently, there is now in place a wide variety of utilities for performing psychophysical experiments using natural images, and for modeling the basic mechanisms with which such images are perceptually analyzed. Second, a number of experiments have been completed to compare various hypotheses about how surfaces are perceptually represented, and to investigate the specific strategies by which image contours are perceptually identified (e.g., as shadows, sharp edges, smooth occlusions, etc.).

Report:
Todd, J.T. & Reichel, F.D. (1989). Ordinal structure in the visual perception and cognition of smoothly curved surfaces. Psychological Review, 96, 643-657.

TITLE: Visual Perception of Features and Objects

PRINCIPAL INVESTIGATOR: Anne Treisman
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R&T PROJECT CODE: 4424251 CONTRACT NO:

Objective:
To conduct experimental studies on feature analysis, the perception of conjunctive features, the effects of extended practice on visual search, the role of attention, object representation for dynamic images, the maintenance of object identity, the unity or grouping of object features, and memory for visual patterns.

Approach:
Experimental studies examine the nature of the stored representation for specific features, the generality of that process for implicit and explicit memory tasks, and the dependence of perception on instructions during the acquisition of information.

Progress:
Research on the perception of conjunctions has focused on possible modifications of feature integration theory to accommodate cases where conjunctions appear to be detected in parallel, and on a more detailed analysis of the constraints on feature integration and the role played by attention. Other projects concerned early vision and the detection of features, the perception of moving objects, the perceptual learning and visual memory for visual patterns after a single or very few exposures, and after extended practice.

Report:
Treisman, A. & Sato, S. (1990) Conjunction search revisited. Journal of Experimental Psychology: Human Perception and Performance. In Press.

TITLE: Neural Models of the Visual Cortex in Information Processing

PRINCIPAL INVESTIGATOR: David C. Van Essen
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(818) 356-6823

R&T PROJECT CODE: 4425083 CONTRACT NO: N000148911192

Objective:
Objective is to determine how information about motion, texture and depth is represented and transformed in early stages of visual processing. Emphasis is on recognition of complex visual forms viewed by task oriented humans and primates.

Approach:
Approach is interdisciplinary and collaborative, combining computational modeling, human psychophysics and primate neurophysiology. Cortical activity in animal experiments will be traced using voltage-sensitive dyes and optical recording techniques.

Progress:
Experiments were conducted to examine the effects of a moving background on the receptive field profiles of neurons in primate visual cortex, area V1. An oscillating, textured background was presented entirely outside the cell's classical receptive field, and responses were mapped to stimuli flashed within the receptive field but at different phases relative to the background motion. Significant motion-induced modulation of neuronal firing rate was found in about 50% of V1 neurons studied.

Report:
Fox, J.M., Van Essen, D.C., Delbruck, T., Gallant, J., and Anderson, C.H. (1991) Dynamic aspects of receptive field organization in area V1 of the macaque monkey. In: Analysis and Modeling of Neural Systems, F. Eckman (Ed).

TITLE: Invariant Learning and Recognition of 3D Object-Part Hierarchies

PRINCIPAL INVESTIGATOR: Allen M. Waxman
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Lincoln Laboratory
(617) 981-2056

R&T PROJECT CODE: 4424267 CONTRACT NO:

Objective:
To modify and extend an existing machine vision system to incorporate the invariant learning and recognition of object-part hierarchies. Such representations are well suited for recognition of variable, articulated, and occluded objects.

Approach:
The work will include both physiological experimentation with monkeys (carried out under sub-contract to D. Perrett at St. Andrews University in Scotland) and computational modeling based on the physiological findings and other findings in the literature.

Progress:
This grant is new in FY91.

PERCEPTUAL SCIENCE

AUDITION

TITLE: Classification of Complex Sounds

PRINCIPAL INVESTIGATOR: Bruce G. Berg
University of Florida
Department of Psychology
(904) 392-1608

R&T PROJECT CODE: 4424260 CONTRACT NO: N0001491J1122

Objective:
Develop a deeper understanding of how human listeners classify and discriminate complex auditory stimuli by uncovering the features and feature weightings used in making psychoacoustic judgments, and by determining how identified features are combined.

Approach:
Psychoacoustic experiments will be carried out in which listeners are required to either discriminate or classify complex acoustic events systematically differing along a variety of spectral and/or temporal dimensions. Various features will be perturbed in appropriate ways and the impact of these perturbations will be assessed by means of COSS analysis. This analysis identifies which of the features investigated are used by a listener in making judgments and how each feature is weighted.

Progress:
This grant is new in FY91.

TITLE: An Electrophysiological and Behavioral Examination of Bimodal Information Processing

PRINCIPAL INVESTIGATOR: David Kobus
Naval Health Research Center
Sustained Operations Department
(619) 553-9389

R&T PROJECT CODE: 4424256 CONTRACT NO: N0001491WR24025

Objective:
To determine the information-bearing parameters used by superior sonar classifiers in making classification judgments, and to determine the relative contributions of visual and auditory cues in making such judgments.

Approach:
Psychophysical experiments will be carried out using auditory, visual or bimodal displays of sonar or sonar-like signals. Subjects will perform a variety of tasks, including classification, discrimination, and similarity ratings. The resulting data will be subjected to multi-dimensional scaling and cluster analysis to extract the features used in making the psychophysical judgments obtained.

Progress:
An experiment is currently underway in which sonar classification performance of experienced sonar technicians was evaluated under three stimulus conditions: auditory signal, visual signal representation, and auditory plus visual presentation. Data analysis will focus on determining whether multimodality presentation facilitates performance, and if so, for what types of target.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: A Source Separation Model of the Mammalian Auditory System

PRINCIPAL INVESTIGATOR: Edwin R. Lewis
University of California, Berkeley
Electronics Research Laboratory
(415) 642-5169

R&T PROJECT CODE: 4424263 CONTRACT NO: N0001491J1333

Objective:
Develop computational models of the mammalian auditory periphery and brainstem nuclei. Derive algorithms for automated acoustic source separation based on principles uncovered by simulation and analysis of model results.

Approach:
Existing models of the cochlea and auditory nerve will be extended and interfaced with models of auditory brainstem nuclei to be developed. Model development will be done within a modular framework so that models can be easily modified to incorporate new hypotheses and adjust the level of biological detail. Model neural elements will be dynamic and generate spike trains, which are likely to be crucial for certain kinds of temporal processing. Various classes of brainstem neurons which exhibit distinct dynamic behaviors, and which are thought to mediate the generation of distinct classes of acoustic image, will be simulated. Psychophysical data on cues important for source separation will be used to constrain the model and guide hypotheses on neural mechanisms.

Progress:
This grant is new in FY91.

TITLE: Central Factors in the Classification of Transient Acoustic Signals

PRINCIPAL INVESTIGATOR: Robert A. Lutfi
University of Wisconsin
Waisman Center on Mental Retardation
(608) 262-7734

R&T PROJECT CODE: 4424226 CONTRACT NO: N0001489J1281

Objective:
The objective is to determine the role of central factors such as learning, memory, and attention in the classification of complex acoustic signals with random variation similar to that occurring in naturally occurring signals.

Approach:
Psychophysical studies of normal hearing humans will be carried out to determine listeners' ability to integrate information across a wide range of stimulus dimensions, to overcome effects of stimulus uncertainty, and to weight information according to its reliability. Quantitative modeling studies will also be carried out to evaluate hypotheses generated by psychophysical experiments. The methods of signal detection theory will be applied in both experimental and modeling components of this project.

Progress:
A series of experiments has been carried out to investigate human listening performance in classification tasks involving multidimensional signals. The results imply that performance depends on the information content of the signal regardless of how the information is packaged in the stimulus. Performance was best for stimuli differing modestly along several dimensions rather than differing greatly along a single dimension.

Report:
Lutfi, R.A. (1990) Informational processing of complex sound. II. Cross dimensional analysis. Journal of the Acoustical Society of America, 87, 2141-2148.

TITLE: Acoustical Cues for Sound Localization

PRINCIPAL INVESTIGATOR: John C. Middlebrooks
University of Florida
Department of Neuroscience
(904) 392-3177

R&T PROJECT CODE: 4424227 CONTRACT NO: N0001489J1427

Objective:
The technical objectives of this study are: (1) to determine possible physical cues that may be used by the central nervous system to compute sound source location by making measurements of sound pressure in the human ear canals; (2) to measure in behavioral experiments the accuracy with which humans localize broad- and narrow-band sounds presented at unknown vertical and horizontal locations.

Approach:
Both acoustical and behavioral experiments will be carried out. In acoustical experiments, transient broad- and narrow-band sounds from a movable free field sound source will be presented to human subjects while sound pressure is recorded from miniature microphones inserted into their ear canals. Spatial dependence of sound pressure levels and interaural level differences will be determined from amplitude spectra as a function of location. Interaural envelope delays will be computed from phase spectra. In behavioral experiments, subjects are asked to turn their head toward the apparent location of the source, and head position is monitored with an electromagnetic device attached to the head. The pattern of localization errors is used to determine possible localization strategies.

Progress:
A series of studies has been completed in which tools were developed for measuring the directional transfer function (DTF) of the human ear. These tools were applied to measure the horizontal and vertical accuracy of broadband sound localization. Performance for sources at 324 locations around each subject was assessed.

Report:
Middlebrooks, J.C. & Green, D.M. (1990) Directional dependence of inter-aural envelope delays. Journal of the Acoustical Society of America, 87, 2149-2162.

TITLE: Dolphin Echolocation: Cognitive and Perceptual Processing Models

PRINCIPAL INVESTIGATOR: Paul E. Nachtigall
Naval Ocean Systems Center
Hawaii Laboratory
(808) 257-5256

R&T PROJECT CODE: 4424262 CONTRACT NO: N0001491WX24173

Objective:
To increase understanding of dolphin acoustic signal processing and to explore the potential application of empirical results for defining an effective signal parsing strategy for input to neural network classifiers.

Approach:
Perform a series of experiments testing the ability of the dolphin to classify objects by means of its active sonar system. Determine by means of synthetic returns what signal components are crucial for accurate classification. Based on the results, design the signal parsing front-end for a neural network signal classifier. Compare performance of the animal and the network.

Progress:
This grant is new in FY91.

TITLE: Models for Continuous Processing of Auditory Signals

PRINCIPAL INVESTIGATOR: Robert F. Port
Indiana University
Department of Computer Science
(812) 855-9217

R&T PROJECT CODE: 4424259 CONTRACT NO: N0001491J1261

Objective:
(1) Carry out psychophysical experiments designed to determine if representations of complex tonal sequences that are learned for sequence recognition tasks are similar to those learned for discrimination tasks. Develop and extend computational models and simulations to incorporate experimentally determined ways in which representations depend on nature of task. (2) Carry out psychophysical experiments designed to determine what invariances are intrinsic to the representation of acoustic patterns in humans. Use results of these experiments to constrain and guide the computational model. Determine what kinds of patterns can be learned given various representations of those patterns.

Approach:
Psychophysical experiments will be performed to investigate human auditory perception capabilities on tasks requiring identification of complex tonal sequences and discrimination of features of sequence components. The effects of changes in rate of tone presentation on performance will also be explored. Results of these experiments will be used to constrain and guide development of a recurrently connected neural network model with separate modules for processing of novel and familiar acoustic patterns. An attempt will be made to determine self-organizing algorithms for learning of temporal patterns in such networks.

Progress:
This grant is new in FY91.

TITLE: Bioacoustic Signal Classification in Cat Auditory Cortex

PRINCIPAL INVESTIGATOR: Christoph E. Schreiner
University of California, San Francisco
Department of Otolaryngology
(415) 476-2591

R&T PROJECT CODE: 4424264 CONTRACT NO: N0001491J1317

Objective:
To explore the physiological principles underlying the spatio-temporal representation of simple and complex signals in the auditory cortex of the cat; and (2) to use the formalized cortical representation as the input (front end) to a self-organizing signal classifier instead of a purely acoustical/spectral representation of complex signals.

Approach:
Experiments will be carried out to map the spatio-temporal patterns of activity produced in the auditory cortex by signals of varying complexity and known acoustical properties. The signal parsing strategies so identified will be incorporated into neural network classifiers as a 'front-end'. The effectiveness of this input parsing will be evaluated in relation to more traditional methods.

Progress:
This grant is new in FY91.

TITLE: Principles of Perception in Bat Sonar

PRINCIPAL INVESTIGATOR: James A. Simmons
Brown University
Department of Psychology
(401) 863-1542

R&T PROJECT CODE: 4424202 CONTRACT NO: N0001489J3055

Objective:
To determine the fine structure of the image of a sonar target as it is perceived by echo-locating bats and to understand the convergence of different representations of that image, i.e., psychophysical, computational, and physiological, that occur during the processes of fusion and formation.

Approach:
Target-ranging experiments employ a jittered-echo procedure to minimize the artifacts introduced by movements of the bat's head and to measure the shape of the acoustic image along an echo-delay or distance axis. Bats are trained in a two-alternative forced-choice procedure to discriminate between a simulated sonar target whose echoes alternate in delay and a simulated target whose echoes have a fixed delay for all transmissions. Echo delay is the acoustic cue used by the bat for the perception of the absolute distance to a target.

Progress:
Experiments aimed at determining the neural representation of complex multi-glint targets revealed that: (a) the absolute target range is extracted from the emission-echo time delay; (b) the bat represents this time delay by performing a neural computation of the cross-correlation between the emission and first glint; (c) the range profile for glints separated by less than the neural integration time is encoded in the compound echo pattern of spectral peaks and notches; (d) from this spectral pattern, the bat extracts the time delays between glints.

Report:
Simmons, J.A. (1989) A View of the world through the bat's ear: formation of acoustic images in echolocation. Cognition, 33, 155-99.

TITLE: Classification of Sonar Transients by Human Listeners

PRINCIPAL INVESTIGATOR: James C. Solinsky
Science Applications International Corp.
(619) 546-6000

R&T PROJECT CODE: 4424261 CONTRACT NO: N0001491C0041

Objective:
(1) Develop a model and simulations of transient sonar signals. (2) Characterize and compare the auditory perceptual space of expert and non-expert listeners for passive sonar transients. (3) Identify the decision surfaces which divide the perceptual space into categories for expert and non-expert listeners. (4) Specify computational model of acoustic signal classification in humans.

Approach:
A parametric model of sonar transients will be developed using bi-modal spectra generated with a Gram-Charlier expansion. Phase will be non-Gaussian. Psychophyscial analysis will employ the technique of multi-dimensional scaling to characterize the perceptual structure for non-speech sounds and underlying perceptual space. Perceptual features will be identified by analyzing the relation between acoustic parameters and axes of the perceptual space. Probe signals will be used to characterize the classification decision surfaces for listeners with different experience levels.

Progress:
This grant is new in FY91.

TITLE: Neural Beamforming: A Role for Phase and Synchrony in Cortical Activity

PRINCIPAL INVESTIGATOR: Steven L. Speidel
Naval Ocean Systems Center
Antisubmarine Warfare Department
(619) 553-1557

R&T PROJECT CODE: 4424271 CONTRACT NO: N0001491WX24269

Objective:
Extend existing adaptive neural network beamformer to provide it with capability of performing sound event segmentation by incorporating mechanisms that make use of information on phase and synchrony of spectral components in the input signal.

Approach:
Input signals will be passed through a filter bank that models properties of the cochlea. Sounds will be segmented according to incidence angle and onset time. As individual beamformer networks begin to focus on a particular stimulus, whose components have common onset time and incident angle, neighboring networks are inhibited and become less able to respond to sounds incident from other angles.

Progress:
This grant is new in FY91.

TITLE: Signal Feature Analysis Using Neural Networks and Psychoacoustics

PRINCIPAL INVESTIGATOR: Nelson F. Steele
Advanced Resource Development Corp.
(301) 997-5600

R&T PROJECT CODE: 400o041sbi03 CONTRACT NO: N0001490C0228

Objective:
To extract and contrast the features used by skilled sonar operators and several types of neural networks in classifying active sonar signals.

Approach:
Active sonar signals of known origin will be presented to sonar technicians and to several types of neural networks. Analyses will be carried out to determine the features used by each classifier in interpreting the signals.

Progress:
Sonar data have been obtained and incorporated into a test regime for comparison of human signal classification performance with and without neural network decision aiding.

TITLE: Committee on Hearing, Bioacoustics and Biomechanics

PRINCIPAL INVESTIGATOR: Milton A. Whitcomb
National Academy of Sciences
(202) 334-2888

R&T PROJECT CODE: 4426124 *CONTRACT NO: N0001487C0342*

Objective:
To provide information and assess status of current programs and to make recommendations on current and anticipated problems relevant to Navy and other federal agencies in the areas of hearing, bioacoustics, and biomechanics.

Approach:
Working groups address: effects of sound on hearing of divers during deep dives; exposure limits for vibration received by personnel in tracked vehicles and helicopters; effect of sonic booms produced by future commercial supersonic transport aircraft; auditory attentional deficit; evaluation of communication systems; aging in the central nervous system as it relates to perception of speech by older persons; and reversibility of presbycusis.

Progress:
A variety of conferences and white papers on research opportunities in hearing, bioacoustics, and biodynamics have been carried out during the past year. Copies of conference reports and white papers have been made available to ONR scientific staff.

PERCEPTUAL SCIENCE

HAPTICS AND SENSORY GUIDED MOTOR CONTROL

TITLE: Study of Neural Feedback and Musculo- Skeletal Mechanics in the Control of Multi-Joint Behavior

PRINCIPAL INVESTIGATOR: Emilio Bizzi and Neville Hogan
Massachusetts Institute of Technology
Department of Brain and Cognitive Science
(617) 253-5769

R&T PROJECT CODE: 4424216 CONTRACT NO: N0001490J1946

Objective:
Objective is to produce biologically plausible computational models of sensorimotor control of limb movement for potential implementation in teleoperated and robotic devices.

Approach:
The approach is a combination of neurophysiological experiments, behavioral investigations, mathematical modeling and theoretical studies of the computational tasks performed by the brain in the control of motor behavior. Model-based experiments are conducted to quantitatively model movement planning and implementation.

Progress:
Microstimulation of restricted areas within the spinal cord neural circuitry produces convergent force fields on the limb end-point, which have a single equilibrium point. Stimulation in other areas of the spinal cord produce only divergent force fields, with no equilibrium point. There appear to be only four discrete regions in the spinal cortex area that controls frog hind limb movement, in which stimulation produces convergent fields. Fields that result from stimulation of more than one area are the vector sum of fields produced by stimulating a single area.

Report:
Fasse, E., Kay, B., and Hogan, N. (1991, in press) Human haptic illusions in virtual object manipulation. Proceedings of 12th Annual Conference. IEEE Engineering in Medicine and Biology Society.

TITLE: Tactile Sensing and Control in Humans and Robotic/Teleoperated Systems

PRINCIPAL INVESTIGATOR: Mark R. Cutkosky
Leland Stanford Junior University
Department of Mechanical Engineering
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R&T PROJECT CODE: 4424257 CONTRACT NO: N0001490J4014

Objective:
Create an integrated tactile sensing system with dynamic as well as conventional tactile and force sensors. Develop signal processing algorithms that extract information needed for dexterous manipulation; determine the basic control modes and reflexes that take advantage of sensory information. Investigate sensor-driven control strategies for precision manipulation in humans and use the findings to develop event-driven control strategies for robotic precision manipulation.

Approach:
Develop sensor configurations that result in largest and fastest signal for incipient slip detection. Use techniques such as adaptive filtering to optimize the sensor system for execution of simple manipulation tasks. Perform mechanical analysis of forces and motions required for a robotic assembly task, and analyze sensory requirements for successful completion of the task. Collaborate with the lab of R. Johansson on experiments aimed at understanding control strategies used by humans on assembly tasks. Use this information in design of sensor-driven control strategies for robotic manipulation.

Progress:
This grant is new. Plans have been made to visit the laboratory of R. Johansson to participate in experiments aimed at understanding sensor-driven control strategies in humans performing precision grasp tasks.

TITLE: Research on Reduced-Capability Human Hands

PRINCIPAL INVESTIGATOR: Nathaniel Durlach
Massachusetts Institute of Technology
Research Laboratory of Electronics
(617) 253-3922

R&T PROJECT CODE: 4424249 CONTRACT NO: N0001490J1935

Objective:
The general objectives of the research are to increase basic knowledge of hand function, aid in the design and evaluation of artificial hands for robotic and teleoperator systems, and provide background for master/slave hand-design decisions.

Approach:
The degradation of analytic and functional manual performance resulting from imposition of a variety of constraints will be investigated experimentally. Functional tests include tasks drawn from those developed at NOSC for testing the TOPS teleoperator system. Constraints include mechanical interferences (e.g., gloves), anesthetics, cold water, and hand impairments of the kinds caused by injury.

Progress:
Facilities for performing tasks and tests to reveal sensorimotor capabilities of reduced capability hands have been developed. Techniques for construction of experimental gloves that reduce tactile sensitivity in a controlled manner have been explored.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: The Cortical Substrate of Haptic Representation

PRINCIPAL INVESTIGATOR: Joaquin M. Fuster
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UCLA School of Medicine
(213) 825-0247

R&T PROJECT CODE: 4425800 CONTRACT NO: N0001489J1805

Objective:
The primary objective of this work is to understand the functional organization of areas of primate cerbral cortex that represent tactile and visual information, with particular emphasis on the interaction of tactile and visual stimuli in the cortical representation of external objects.

Approach:
The role of posterior parietal cortex in the representation of physical objects will be explored by examining the effects of reversible cryogenic lesions of this cortical area in monkeys on short-term memory of haptically or visually perceived objects. Functional organization of parietal neurons during short term memory tasks will explored with microelectrode recording. Single unit recordings will also be analyzed to investigate neuronal mechanisms underlying attention to an object.

Progress:
The effects of cooling posterior parietal cortex areas 5 and 7 on behavior and on the activity of neurons in prefrontal cortex were examined in monkeys performing visual discrimination tasks with delayed choice. Most prefrontal units usually decreased their firing during parietal cooling. Parietal cooling also induced misreaching, slow and inaccurate ocular movements, and longer reaction time. It did not affect number of correct choices.

Report:
Quintana, J., Fuster, J. and Yajeya, J. (1989) Effects of cooling parietal cortex on prefrontal units in delay tasks. Brain Research, 503, 100-110.

TITLE: Mechanisms of Eye-Hand Coordination

PRINCIPAL INVESTIGATOR: Apostolos P. Georgopoulos
The Johns Hopkins University
Department of Neuroscience
(301) 955-8334

R&T PROJECT CODE: 4424224 CONTRACT NO: N0001488K0751

Objective:
To elucidate the mechanisms of eye-hand coordination at the psychophysical (behavioral), neurophysiological, and computational levels.

Approach:
To define the behavioral capabilities of human and monkey subjects in eye-hand coordination, characterize the patterns of activity of single cells in the monkey motor cortex during eye-hand coordination tasks, and to model the involvement of neuronal populations in the motor cortex during the performance of such tasks.

Progress:
The effects of an external constant bias force on information transmitted by the direction of isometric force in 2-dimensional space by human subjects were studied using an isometric manipulandum and visually displayed information on force. When no force bias was applied, the force exerted by the subject was close to the visually defined direction. When a constant bias force of 110 gram-force was applied, the direction of the force exerted by the subject changed with time so that eventually the vector sum of the bias force and the applied force was close to the visually defined direction. The amount of information transmitted in these two cases did not differ significantly, suggesting that there is efficient control of isometric forces in visuomotor coordination.

Report:
Massey, J., Drake, R., and Georgopoulos, A. (1990, in press). Cognitive spatial-motor processes. 5. Specification of visually-guided isometric forces in two-dimensional space: Time course of information provided and effect of constant bias force. Experimental Brain Research.

TITLE: The Anthroform Biorobotic Arm

PRINCIPAL INVESTIGATOR: Blake Hannaford
University of Washington
Department of Electrical Engineering
(206) 543-4043

R&T PROJECT CODE: 4424270 CONTRACT NO: N0001491J1760

Objective:
The objectives are: (1) the development of a robot arm controller that is based on known principles of motor control in biological systems; and (2) integration of this controller with a robot arm whose design is based on known principles of musculo-skeletal mechanics.

Approach:
The funds provided by this action will be used to purchase an anthroform arm and a SUN SPARCstation which will provide the developmental context and the programming capability needed to carry out the planned work.

Progress:
This grant is new in FY91.

TITLE: Automatic Characterization of the Human Operator Dynamics and Its Incorporation into Telerobot Control

PRINCIPAL INVESTIGATOR: John M. Hollerbach
McGill University
Department of Biomedical Engineering
(514) 398-6736

R&T PROJECT CODE: 4424239 CONTRACT NO: N0001490J1849

Objective:
To develop scientific instrumentation and methods for the analysis of single joint, quasi-static movement in human operators and manipulators.To utilize knowledge of human operator dynamics to improve teloperation of the manipulator for pursuit tracking.

Approach:
Determine the mechanical properties of the actuator linkage of the experimental apparatus. Determine overall human operator dynamics in visual pursuit tracking of position with several forms of target presentation. Apply a random force-step to the wrist of human operators and instruct the operator to resist that force in such a way that the elbow joint does not change. Several methods are developed to indicate when the elbow angle has been perturbed by the force step.

Progress:
During the first year of funding a one degree-of-freedom master-slave laboratory system was developed. This system will be used as the basis of experimental work to be carried out during the second two years of the project.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Sensory Motor Control of Dexterous Manipulation by Humans

PRINCIPAL INVESTIGATOR: Roland S. Johansson
University of Umea
Department of Physiology
46-90-165621

R&T PROJECT CODE: 4424250 CONTRACT NO: N0001490J1838

Objective:
To determine quantitatively the processes by which sensory information is integrated with automatic motor control to adapt human motor processes to the load demands placed on the motor system to control the movement and position of active objects.

Approach:
Muscle synergies and activation patterns are quantitatively analyzed from intrinsic and extrinsic muscles of the hand and activity in single afferent mechanoreceptors of the hand is also recorded, as a human operator restrains the position of an object (handle under random load-forces). The load and grip forces of the thumb and index fingers are independently measured. The position of the object is registered, as are the small slips of the grasped object.

Progress:
In a study designed to investigate how precision grip is regulated with respect to individual digits, subjects lifted an object with two parallel grip surfaces and a low center of gravity, using the grip between the tips of the thumb and the index finger. The friction between the object and digits was varied independently at each digit by changing the contact surfaces between lifts. Results suggested that a partitioning of load force between digits is governed by an automatic lower-level control (no-slip strategy), subordinated to a higher-level control related to the required total tangential and normal force. The no-slip control strategy is dependent on tactile afferent input.

Report:
Johansson, R. and Westling, G. (1991). Afferent signals during manipulative tasks in humans. In: Information Processing in the Somatosensory System, Franzen and Westman (Eds.) Macmillan Press.

TITLE: Motor Learning in Speech and Limb Movements: A Computational Approach

PRINCIPAL INVESTIGATOR: Michael I. Jordan
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
(617) 253-1696

R&T PROJECT CODE: 4424253 CONTRACT NO: N0001490J1942

Objective:
The overall objective is the development of a computational theory of the production of coordinated movement in biological systems, both of the limbs and of the vocal apparatus.

Approach:
The approach will entail implementation of simulation models of an arm and a vocal tract. Two-joint and three-joint arm models will be simulated using standard rigid body dynamical equations, and will include simulated agonist and antagonist muscles at each joint based on a simple model of muscle dynamics. Vocal tract modeling will involve (1) a geometric model that relates articulator positions to vocal tract area functions, and (2) an acoustic model that combines vocal tract area functions with a source model to produce an acoustic spectrum.

Progress:
Development of algorithms to be implemented in simulations of arm and vocal tract control is underway.

TITLE: Complex Sensorimotor Behavior: Biological Control Structures and Constraints

PRINCIPAL INVESTIGATOR: J.A.S. Kelso
Florida Atlantic University
Center for Complex Systems
(305) 538-2230

R&T PROJECT CODE: 4424223 CONTRACT NO: N0001488J1191

Objective:
To develop the theoretical and empirical base for a unified control theory of motor function, applicable across both rhythmic and discrete movement domains.

Approach:
To conduct psychophysical and motor performance experiments with human subjects and develop non-linear dynamical analyses of the results of these experiments, leading to a formal theoretical formulation of the dynamics of sensory-guided reaching and grasping behavior.

Progress:
Motor behavior phase transitions, which can give insight into motor control principles, were investigated in multijoint limb movements. As the frequency of repetitive limb movements was increased, there was an abrupt switch in the phase relation between movements about wrist and elbow joints, and also between corresponding neuromuscular timing patterns. Stable phasing patterns depended upon the spatial orientation of the forearm. Thus, two control parameters which govern qualitative changes in motor behavioral pattern are frequency and spatial orientation.

Report:
Kelso, J.A.S., Buchanan, J.J. and Wallace, S.A. (1990, in press) Order parameters for the neural organization of single, multijoint limb movement patterns. Experimental Brain Research.

TITLE: Peripheral Neural Mechanisms of Haptic Touch: Softness and Shape

PRINCIPAL INVESTIGATOR: Robert H. LaMotte
Yale University ,
School of Medicine
(203) 785-2802

R&T PROJECT CODE: 4424218 CONTRACT NO: N0001491J1566

Objective:
The objective is to develop the psychophysical and neurobiological basis for biologically plausible computational models of human hand grasping and object manipulation for potential implementation in teleoperated and robotic devices. A computational theory of touch will be developed.

Approach:
Psychophysical data from humans and monkeys and physiological data from monkeys will be gathered to determine the capabilities of these systems to discriminate softness and shape, and to determine the neural code underlying these discrimination capabilities. Concepts from mechanics of deformable media and adaptive control theory will be used in the development of computational theory of touch.

Progress:
(1) Psychophysical studies showed that tactile information alone, independent of kinesthetic information, is adequate to account for human softness discriminability. (2) Neurophysiological findings indicate that indentation depth and skin curvature are best encoded in slowly adapting (SA) afferent activity while indentation velocity and rate of change of skin curvature are represented in both SA and rapidly adapting (RA) responses. (3) Analysis of mechanics of contact suggests that receptors in the skin respond to stresses and strains that are blurred versions of surface pressure and curvature.

Report:
Srinivasan, M., Whitehouse, J., and Lamotte, R. (1990). Tactile detection of slip: surface microgeometry and peripheral neural codes. J. Neurophys., 63:1323-1332.

TITLE: Contact Biomechanics in Tactile Sensing

PRINCIPAL INVESTIGATOR: Mandayam Srinivasan
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Research Laboratory of Electronics
(617) 253-2512

R&T PROJECT CODE: 4424268 CONTRACT NO: N0001491J1454

Objective:
Obtain dynamic video images of fingerpad contact areas; measure forces of contact between fingerpads and objects varying in shape, compliance, and texture during active and passive touch. Use results to explain the biomechanical processes that give rise to physiological and psychophysical data, and also to specify inputs to computational model of touch sensing.

Approach:
Video microscopy will be used to record high resolution images of contact regions between fingerpads and transparent test objects for two extremes of magnification, from the whole pad to single ridges. A tactile stimulator will apply test objects to the passive fingerpad. Data will also be collected during active touch. contact modes will include normal, tangential without slip, and tangential with slip. Artificial tactile sensor arrays will be used in some experiments to measure force distribution within the contact region.

Progress:
This grant is new in FY91.

PERCEPTUAL SCIENCE

HUMAN FACTORS TECHNOLOGY

TITLE: Electrophysiological Studies of Selective Attention and Resource Allocation

PRINCIPAL INVESTIGATOR: Steven A. Hillyard
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Department of Neurosciences
(619) 534-7497

R&T PROJECT CODE: 4424232 CONTRACT NO: N0001490J1911

Objective:
To evaluate the utility of evoked-potential methods for the on-line assessment of operator cognitive states (alertness, attentional focus) during tasks requiring the monitoring of several sources of information.

Approach:
An irrelevant probe technique is employed to elicit event-related potentials (N1 and N2 waves) to index the allocation of attention between competing tasks and competing sensory channels. Another event-related potential (P300) is utilized to assess decision confidence and signal detectability during sustained task (simulated sonar) performance. Workload conditions are varied by manipulating the signal-to-noise ratio and the frequency of the target presentations.

Progress:
In a series of experiments, several different ERP components were found to be reliably associated with target detection performance over the half-hour recording session. These components include the P300, and the N1 and P2 waves.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Decision Making in Naval Command Teams

PRINCIPAL INVESTIGATOR: David L. Kleinman
University of Connecticut
Dept of Electrical and Systems Engineering
(803) 486-3066

R&T PROJECT CODE: 4429010 CONTRACT NO: N0001488K0545

Objective:
To investigate decision strategies, information structures, communication protocols, and process feedback as mechanisms to improve coordination in resource allocation and management tasks in command-and-control systems.

Approach:
A testbed implemented as a composite warfare commander distributed dynamic decisionmaking simulation is utilized for the conduct of experiments that investigate the effectiveness of decision strategies under time stress, degraded communications, and resource constraints. Other experiments will examine the role of a leader in (re)allocating resources and different modes of resource transfer within a team, and the manipulation of the information structure of the team for the reduction of resource contention conflicts.

Progress:
A simulation was carried out with four teams in an effort to identify the types of conflict arising in a team (due to human biases, etc.), analyze them, and suggest methods to reduce the conflicts. Preliminary analysis of the data indicate that feedback--consisting of reports on the other team members' performance--increases team performance. This effect was most pronounced when team members were experts of different target types (e.g., aircraft versus submarines). When team members had common expertise, feedback had no measurable effect on team performance.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Effects of Fatigue on Skilled Performance

PRINCIPAL INVESTIGATOR: Arthur F. Kramer
University of Illinois
Institute of Aviation
(217) 333-2186

R&T PROJECT CODE: 4429015 CONTRACT NO: N0001490J1586

Objective:
To determine the sensitivity of measures of event-related potentials for the assessment of real-time variations in processing demands for multi-task situations. To examine the efficacy of workload assessment techniques (primary and secondary task measures; irrelevant probe techniques) for multi-task performance in real-time.

Approach:
Human performance measures, subjective ratings, and event-related potentials are collected from operators during multi-task situations. Different techniques are applied to the event-related-potential data to determine the amount and type of data that optimally discriminate performance among several difficulty levels and types of tasks. The goal is to develop a single-trial pattern-recognition technique for on-line assessment of operator state.

Progress:
Several experiments have been conducted to assess the efficacy of alternative techniques for assessing the mental workload demands of Navy-relevant information processing tasks carried out over protracted periods of time.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: An Integrated Computational Model of a Complex Human Behavior

PRINCIPAL INVESTIGATOR: William R. Uttal
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R&T PROJECT CODE: 4429011 CONTRACT NO: N0001491J1456

Objective:
To conduct simulations that test a software system for the integration of existing algorithms for the detection, localization, and classification of 3-D objects in the underwater environment. To evaluate the general utility of the simulation as a test bed for refinements of the computational algorithms.

Approach:
To collect and integrate a collection of individual computational algorithms into a coherent software system capable of simulating the performance of a 'swimmer' that is required to detect and recognize regular geometrical objects, locate them in 3-D space, and then navigate toward them.

Progress:
The expansion effort builds on the success during the first two years of the PIs program of research leading toward development of an autonomous underwater vehicle capable of navigation, target detection, and target identification. In its current form, the system uses visual information only. In the expansion, it will be enhanced by the capability to incorporate sonar information as well.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

BIOLOGICAL INTELLIGENCE

COMPUTATION IN LARGE NEURAL NETWORKS

TITLE: Development of Multi-Channel Sonar Biotelemetry Systems for Analysis of Motor Pattern Modulation

PRINCIPAL INVESTIGATOR: Joseph Ayers
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Department of Biology
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R&T PROJECT CODE: 4426355 CONTRACT NO: N0001491J1822

Objective:
The objective is to develop a multi-channel sonar biotelemetry system which will allow monitoring of feeding and stomatogastric systems in a natural environment. This work will provide an ethological context for the interpretation of in vivo experiments on modulation of stomatogastric central pattern generators now in progress.

Approach:
With the development of the multichannel sonar biotelemetry system, the following questions can be answered: Under what conditions are different motor patterns expressed in the natural environment? What is the long-term organization of motor programs and interactions of motor programs? How adaptable are natural motor generating patterns and does this adaptability resemble the current in vitro models?

Progress:
This grant is new in FY91.

TITLE: Neural Networks for Adaptive Control

PRINCIPAL INVESTIGATOR: Andrew Barto
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(413) 545-2109

R&T PROJECT CODE: a44e006 CONTRACT NO: N0001489F0128

Objective:
The objectives of this research are to (a) compare neural network and conventional approaches to robust and adaptive control, (b) develop novel network architectures and learning methods specialized for control, and (c) test network based control methods on control tasks for which expert controllers do not currently exist.

Approach:
Neural networks will be investigated for controlling systems with hard non-linearities in the form of transitions between modes. Reinforcement learning methods will be used to select between mode controllers, including the use of cascaded back-propagation networks. Adaptive networks will be used to model a feedback control process with pulse-width modulation inputs, in order to identify the inverse of this nonlinear process. Networks will be compared with reinforcement learning and with conventional solutions on a time-optimal control problem.

Progress:
Implemented and applied ANN control method to nonlinear control problem (to control temperature according to predetermined reference for continuously stirred second-order chemical reaction). Developed and illustrated use of simple, hierarchical ANNs that tailor network architecture to specific problem characteristics.

Report:
Yee, R.C., Saxena, S., Utgoff, P.E., Barto, A.G. (1990) Explaining temporal-differences to create useful concepts for evaluating states. AAAI-90 Conference.

Barto, A.G. (1990) Connectionist learning for Control. In: Neural Networks for Control. Eds. W.T. Miller,III, R.S. Sutton, P.J. Werbos, MIT Press, Cambridge, MA.

Gullapalli, V.A. (1991) Stochastic reinforcement learning algorithm for learning real-valued functions. Tech Report.

Outside Funding:
Funds for this grant are provided by DARPA.

TITLE: Changes in Neuronal Network Properties Induced by Learning and Synaptic Plasticity: A Nonlinear Systems Approach

PRINCIPAL INVESTIGATOR: Theodore W. Berger
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Dept of Behavioral Neuroscience
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R&T PROJECT CODE: 4426817 CONTRACT NO: N0001490J4000

Objective:
Investigate potential changes in system properties of the hippocampus induced by discrimination reversal conditioning of the nictitating membrane (NM) response. Classical conditioning of the rabbit NM response will be used in these experiments because it is one of the most widely used behavioral paradigms for studying the neuronal substrates of associative learning in mammals. The second objective is to produce a computational structure which simulates the hippocampal system functions of learning and memory.

Approach:
The approach of this proposal is an in-depth study of the functional network properties of the hippocampal formation, a brain structure long known to be critical for learning and memory functions. The first phase utilizes nonlinear systems analytic techniques to characterize the transformational properties of networks of neurons comprising the hippocampus, and in defining the contributions to network properties of individual subpopulations of hippocampal neurons. The second phase, involves the formulation of a state-space model of hippocampal system function based on results from the nonlinear systems characteristics of the hippocampus.

Progress:
PI has described electrophysiological characteristics of a heretofore unstudied hippocampal pathway. These results have been incorporated into his model.

Report:
Yeckel, M. and Berger, T. (1990) Feedforward excitation of the hippocampus by afferents from the entorhinal cortex: redefinition of the role of the trisynaptic pathway. Proceedings of the National Academy of Sciences, 87 5832-5836.

Berger, T., Barrionuevo, G., Levitan, S., Krieger, D., and Sclabassi, R. (1991) Nonlinear systems: analysis of network properties of the hippocampal formation. In: Neurocomputation and Learning: Foundations of Adaptive Networks. Moore, J. and Gabriel, M. (Eds.) MIT Press.

TITLE: Neural Network Approaches to Computer Speech Recognition

PRINCIPAL INVESTIGATOR: Ronald A. Cole
Oregon Graduate Institute
Department of Computer Science & Engineering
(503) 690-1151

R&T PROJECT CODE: 4426409 CONTRACT NO: N0001491J1482

Objective:
The work will move from speaker-independent recognition of isolated letters to systems that recognize naturally spelled letter strings. The objective is to demonstrate a system that is able to recognize names from their spellings.

Approach:
The PI will investigate recognition strategies that use neural networks to identify distinctive features in the signal and use these feature values to recognize words. His method will be evaluated using the DARPA spellmode database.

Progress:
This grant is new in FY91.

TITLE: Theoretical and Experimental Research into Biological Mechanisms Underlying Learning and Memory

PRINCIPAL INVESTIGATOR: Leon N. Cooper
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Center for Neural Science
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R&T PROJECT CODE: 4426830 CONTRACT NO: N0001491J1316

Objective:
Detailed objectives include the following: to clarify the dependence of learning on synaptic modification, to elucidate the principles that govern synapse formation or modification - both local factors and global information such as that which may be delivered and/or mediated by neuromodulators, to use principles of organization that can account for observations on a cellular level to construct network models that can compute, and reproduce higher level cognitive acts.

Approach:
Approaches include both theory and experiment. Theoretical and experimental consequences of the hypothesis that synapse modification is dependent on local information (in visual cortex) in accordance with theoretical ideas the authors have developed, as well as by global instructions affecting large numbers of synapses and coming from neuromodulators. Various principles that appear to be operating on the cellular level will be used to construct models of higher level functions, including various network models for memory storage, computation and language acquisition.

Progress:
Bear et al. (1990) tested the effect of APV (a NMDA blocker) continuously infused into visual cortex. Visually deprived neurons within 2 mm of the cannula showed a shift in ocular dominance to the deprived eye suggesting environmental and glutamate effects are additive. A possible connection between BCM learning and a statistical framework for the parameter estimation problem in unsupervised learning was developed (Intrator,1990).

Report:
Bear, M. F., Gu, Q., Kleinschmidt, A. & Singer, W. (1990). Disruption of experience-dependent synaptic modifications in the striate cortex by infusion of an NMDA receptor antagonist. J. of Neuroscience, 10, 909-925.

Intrator, N. (1990) A neural network for feature extraction. In: Proceeding in Neural Information Processing II. Ed. D Touretzky. Morgan Kaufman Pub.

TITLE: Net Technical Assessments of ANN (Neural Network) Technologies

PRINCIPAL INVESTIGATOR: Robert B. Davidson
Science Applications International Corp.
Technology Research Group
(703) 821-4418

R&T PROJECT CODE: a44f003 CONTRACT NO: N0001489C0243

Objective:
The objective of the study is to: (a) evaluate the comparative performance capability of neural networks applied to signal processing tasks (incl: sonar signal identification, and automatic target recognition), and (b) evaluate the emerging national and international technological capabilities in this area.

Approach:
Preparation of a computerized database of neural network technology involves (a) a thorough review and analysis of publications, and technical reports, and (b) host symposia of nationally recognized experts on neural network theory and technology. This team includes several current ONR contractors in ONR's ARI in Biological and Electronic Neural Networks: Leon Cooper, Jerome Feldman, John Hopfield, Carver Mead, and Terrence Sejnowski. Three state-of-the-art symposia will be conducted on the three main topics of the DARPA program: (a) Comparative Performance of Neural Networks, (b) Theory & Modelling, and (c) Hardware Technology.

Progress:
Developed a database on neural network activities worldwide, including DARPA funded efforts. This database management system was written in 4th Dimension for Macintosh. Prepared briefing materials summarizing state of this technology. Planned and participated in site visits to European and Japanese research centers involved in neural net technology as the basis for assessment of research opportunities in this area. Organized and hosted a conference of leading US neural net researchers and prepared report based on proceedings.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Selective Recognition Automata

PRINCIPAL INVESTIGATOR: Gerald M. Edelman
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(212) 570-8975

R&T PROJECT CODE: 4426129 CONTRACT NO: N0001488K0411

Objective:
The major goal of this project is to carry out critical tests of the neuronal group selection theory that will bring selective automata closer to practical application. Specific technical objectives: to account for the regulation of plastic changes in topographic cortical maps, to demonstrate associative learning in selective recognition systems, to study mechanisms for figure-ground discrimination and perceptual constancy in selective systems, to generalize the concept of topographic maps to encompass "cognitive maps" in world-centered coordinate frames, and to represent temporal sequences of events in selective network systems.

Approach:
An approach called "synthetic neural modelling" will be applied to the objectives. This approach depends on starting with a coherent theory of brain function and testing that theory by constructing model automata that follow principles of biological evolution and development. A special purpose network simulation device will be designed and constructed to facilitate the research and to begin the investigation of practical devices based on selection principles.

Progress:
The PI has described a major model of visual cortical processing that incorporates 13 basic cortical areas with a total of 222K neurons and 8.5 million synapses.More detailed specifications have been provided for Darwin III.

Report:
Finkel, L. and Edelman, G. (1989) Integration of distributed cortical systems by reentry: A computer simulation of interactive functionally segregated visual areas. J. of Neuroscience, 9: 3188-3208.

Reeke, G.,Sporns, O. and Edelman, G. (1991) Synthetic neural modelling: The "Darwin" series of recognition automata. in C. Lau (ed.) Proceedings of the IEEE.

TITLE: Synaptic Structural Effects of Long-Term Potentiation in the Hippocampal Formation

PRINCIPAL INVESTIGATOR: William T. Greenough
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R&T PROJECT CODE: 4426640 CONTRACT NO: N0001489J1556

Objective:
Long term potentiation (LTP) is a long lasting increase in the responsiveness of neurons brought about by high-frequency activation of their input fibers. A similar phenomenon occurs in response to behavioral learning or exploratory activity. An algebraic relationship exists between the behaviorally-elicited and the artificially-elicited phenomena, such that behavioral LTP "subtracts" from that which can be elicited with electrical stimulation. This suggests involvement in memory. Understanding how the brain alters its cells to encode memory will be of value, both to those attempting to devise learning systems involving neurally-inspired architecture and to those whose goal is understanding higher order aspects of brain organization in learning, memory, and cognitive function

Approach:
The work requires the use of a number of anatomical, biochemical, and neurophysiological techniques. Many of these techniques are implemented by studying hippocampal tissue wherein chemical and anatomic qualities have been changed as a function of "experience". These changes can either be induced in vitro or in vivo, and the tissue can be removed and kept alive for long periods under appropriate conditions. The approach is to use this model system to understand mammalian learning and memory.

Progress:
PI has provided first evidence that synaptic activation can trigger protein spines and dendrites directly (i.e. no soma required).Also, new synapses form during "kindling", an LTP-like phenomenon.

Report:
Greenough, W.T. (1991) Mechanisms of behaviorally-elicited and electrically-elicited LTP. Int'l. Journal of Neurology.

Black, J. and Greenough, W.T. (1990) Developmental approaches to the memory process. In: Learning and Memory: A Biological View, J.Martinez and R. Kesner (Eds.) Academic Press.

TITLE: Three-Dimensional Organization of Circuits in the Extrapyramidal Motor System

PRINCIPAL INVESTIGATOR: Philip M. Groves
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Department of Psychiatry
(619) 534-3736

R&T PROJECT CODE: 4426637 CONTRACT NO: N0001489J1254

Objective:
The experimental work funded by this action will provide insights into the neostriatal circuitry underlying the guidance and execution of voluntary movement. These insights may be used to build a new generation of robotic devices.

Approach:
Using computer-assisted three-dimensional reconstruction, the PI will continue to analyze the 3-D organizational framework for neostriatal motor circuitry.

Progress:
PI has provided a statistical analysis of proportions of neuron types in motor thalamus. He has also demonstrated that execution of movement by cerebral cortex is modulated by dopamine release within the caudate nucleus.

Report:
Sawyer, S., Young, S. and Groves, P. (1989) A quantitative Golgi study of anatomically identified subdivisions of motor thalamus in the rat. J. of Comparative Neurology, 286: 1-27.

Garcia-Munoz, M., Young, S. and Groves, P. (1991, in press) Terminal excitability of the cortico-striatal pathway: I. regulation by dopamine receptor stimulation. Brain Research.

TITLE: Training in Methods In Computational Neuroscience

PRINCIPAL INVESTIGATOR: Harlyn O. Halvorson
Marine Biological Laboratory
(508) 548-3705

R&T PROJECT CODE: 442h005 CONTRACT NO: N0001491J1739

Objective:
The primary aim of the course is to provide the 20 participants with the tools to simulate the functional properties of those neural systems of interest as well as to understand the general advantages and disadvantages of this experimental approach.

Approach:
The lectures are presented by the course directors (James Bower & Christof Koch-Caltech) and invited faculty including Paul Adams, Dan Alkon, Richard Andersen, John Hildebrand, John Hopfield, Rudolfo Llinas, John Rinzel, David Rumelhart, Idan Segev, Terrence Sejnowski, David Van Essen and Christof Von der Malsburg. The computer laboratory provides students with the opportunity to begin simulations of neural systems. The lab will be equipped with Sun graphics workstations running the General Network Simulation System which was created with ONR support by James Bower.

TITLE: Silicon Association Cortex

PRINCIPAL INVESTIGATOR: Dan Hammerstrom
Oregon Graduate Institute
Department of Computer Science & Engineering
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R&T PROJECT CODE: 442h020 CONTRACT NO: N0001490J1349

Objective:
The objective is the silicon implementation of two existing cortex-like models. Implementation of basic silicon cortex will greatly accelerate the development of neurobiological models by providing a means for much speedier and cost effective simulation.

Approach:
The PI will use only state-of-the-art CMOS technology, since neural networks will only be viable commercially when implemented in cheap, mass producible technology. The close, active collaboration between the hardware designers and the wetware scientists will ensure a faithful representation of the model.

Progress:
Work completed includes construction of simulators, modifications for independent partitioning of subclusters, and preliminary studies of phoneme clustering. Work in progress includes outlining convergence proofs and implementing pattern rescaling to provide high-precision vector quantization with low-precision arithmetic hardware.

Report:
Means, E. and Hammerstrom, D. (1991, in press) A proposed architecture for a second generation neurocomputer. Olfaction as a Model System for Computational Neuroscience. Davis, J. and Eichenbaum, H., (Eds) MIT Press.

Leen, T., Means, E. and Hammerstrom, D. (1990) Analysis and VLSI implementation of self-organizing networks. Proceedings of the Neural Networks for Sensory and Motor Systems Workshop. Eckmiller,R.,(Ed.) North Holland.

TITLE: Brain-Style Computing with Neural Networks

PRINCIPAL INVESTIGATOR: Lawrence S. Hoffheimer
National Foundation for Brain Research
(202) 293-5453

R&T PROJECT CODE: 4426052 CONTRACT NO: N0001491J1631

Objective:
The objective of this conference is to introduce the new technology of neural networks to the public, and to neuroscientists and representatives from various federal agencies and congress, to enable them to grasp the potential of this technology.

Approach:
This conference will be held in Wash. DC. It will consist of an introduction to neural nets followed by 8 lecturers, including representatives from ONR, and ONR PIs Walter Freeman (Berkeley), Leon Cooper (Brown), James Houk (Northwestern), and Richard Granger (UCI). This will be followed by a panel discussion which will include representatives of government funding agencies and Navy labs.

TITLE: Adaptive Control of Limb Motion by Brains and Robots

PRINCIPAL INVESTIGATOR: James C. Houk
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Department of Physiology
(312) 908-8219

R&T PROJECT CODE: 4426126 CONTRACT NO: N0001490J1822

Objective:
The proposal is designed to advance knowledge about how the cerebellum might mediate adaptive feedforward control, and to apply this information to robotics.

Approach:
The investigators will conduct computer simulations of motor systems, in the form of simulated neural networks, that are based on the anatomy and physiology of the cerebellum. More specifically, the investigators are interested in the functional and computational significance of the findings that will result from the mapping of mossy-fibre inputs to cerebellar cortex. Consequently, the investigators will develop and simulate networks of neuron-like units whose architectures and roles in motor control are based on anatomical and physiological knowledge.

Progress:
PI has proposed and described a network, based on cerebellum, that is composed of an array of pattern generators. Motor programs can be stored, retrieved, and executed using adjustable pattern generator modules.

Report:
Houk,J. (1990) An adaptive sensorimotor network inspired by the anatomy and physiology of the cerebellum. In: Neural Networks for Control. Miller, W., Sutton, R. and Werbos, P., (Eds) MIT Press.

Houk, J. and Barto, A. (1991) Distributed sensorimotor learning. In: Tutorials in Motor Behavior II. Stelmach, G. and Requin, J. (Eds.) Elsevier, Amsterdam.

TITLE: Neural Mechanisms of Preparatory Processes in Stimulus-Response Associations and Movement Programming

PRINCIPAL INVESTIGATOR: Sylvan Kornblum
Regents of the University of Michigan
Department of Psychology
(313) 763-1101

R&T PROJECT CODE: 4426310 CONTRACT NO: N0001489J1557

Objective:
The objective is to provide a systematic account of the excitatory and inhibitory patterns of activity that occur in the sensory-motor transfer structures of the brain.

Approach:
Two series of experiments are planned. The first addresses the question of identifying and characterizing neural associative structures underlying the preparation of whole movements. During the behavioral stimulus-response compatibility paradigm, human cortical activity patterns will be monitored with PET scans, and monkeys cortex will be recorded electrophysiologically. The second addresses the question of neural structures involved in coding movement features in simple voluntary movement. During performance of the movement priming paradigm, single unit recordings will be obtained from motor, premotor, and parietal cortices.

Progress:
Behavioral Work (UM): The representational and processing aspects of a model has been developed which provides a framework for analysis of Stimulus-Stimulus and Stimulus-Response compatibility tasks Tests of this model have shown that S-R ensembles with dimensional overlap display a strong mapping effect.
Neurophysiological Work - CNRS (Marseille): Single unit recordings performed in monkeys have revealed that area 5 and 6 neurons may participate in a common cortical mechanism of S-R association in movement planning. Neurons in area 5 show a differential location according to somesthetic or sensorimotor properties.

Report:
Kornblum, S., Hasbroucq, T. & Osman, A. (1990) Dimensional overlap-cognitive basis of stimulus-response compatibility: A model and taxonomy. Psych. Rev., 97, 253-270.

Riehle, A. (1991) Visually induced signal-locked activity changes in precentral motor areas of the monkey: Hierarchical progression of signal processing. Brain Res. (in press)

TITLE: Hippocampal Modulation of Associative Learning

PRINCIPAL INVESTIGATOR: Zafra Lerman
Columbia College Chicago
Science and Mathematics Department
(312) 663-1600

R&T PROJECT CODE: 4426322 CONTRACT NO: N0001491J1764

Objective:
The PI will complete a biologically constrained hippocampal model and test its predictions in biological experiments.

Approach:
Real-time descriptions of behavior and neural activity will be simulated and contrasted with relevant experimental data including latent inhibition, blocking, overshadowing, and acquisition-extinction.

Progress:
This grant is new in FY91.

TITLE: Analysis and Simulation of a Cortical Network

PRINCIPAL INVESTIGATOR: Gary Lynch
University of California, Irvine
Department of Psychobiology
(714) 856-4274

R&T PROJECT CODE: 442h010 CONTRACT NO: N0001489J1255

Objective:
The objective is an understanding of the types of learning operations carried out by simple cortical networks. This requires research at four different levels: (1) neurobiology, (2) simulations and mathematical analysis, (3) behavioral neurophysiology (i.e., chronic recording), and (4) behavior. Results obtained in each of these areas will be used to inform, guide, and constrain studies at the other levels, as well as providing tests of predictions arising from the model being constructed.

Approach:
Researchers have historically sought to investigate the remarkable memorial capacities of brain by trying to identify physiological, anatomical, or chemical correlates of specific types of behavioral learning. This effort goes in the reverse direction. The PI's first ask how complex sets of physiological variables govern the collective activity of neurons in brain networks, and second if these aggregate activities might produce recognizable behavioral events. Using this strategy, they hope to develop general formulations stated in basic biological terms that relate physiology and anatomy to particular aspects of memory.

Progress:
The PI has shown sequential connections in a well-defined anatomical circuit to possess a series of distinctly different variants of synaptic plasticity that provide the bases for a series of logically related memory operations.

Report:
Ambrose-Ingerson, J., Granger, R., and Lynch,G.(1990) Simulation of paleocortex performs hierarchical clustering. Science, 247, 1314-1348.

Lynch, G. and Granger, R. (1991, in press) Serial steps in memory processing: Possible clues from studies of plasticity in the olfactory-hippocampal circuit. In: Olfaction as a Model System for Computational Neuroscience. J. Davis and H. Eichenbaum (Eds.) MIT Press.

TITLE: Intelligent Controls Research Using the Dexterous Robotic Hand and Neural Networks Laboratory

PRINCIPAL INVESTIGATOR: Robert McLauchlan
Texas A&I University
Department of Mechanical Engineering
(409) 845-1264

R&T PROJECT CODE: 4421200 CONTRACT NO: N0001491J1365

Objective:
The objectives are to (a) develop new strategies for intelligent control of robotic arm-hand systems, (b) develop a new graduate research program in intelligent control.

Approach:
The investigators will develop new software simulations of control algorithms and neural network/fuzzy logic systems for controlling (a) an experimental 2-link arm/scissor hand system and (b) a Remotec arm plus Salisbury/JPL dextrous hand system. Software implementations of basic primitive operations for robotic hands in open-loop or sensory feedback conditions will be developed, as well as a task planner for hand functions. Hierarchical neural nets and fuzzy logic will be examined for computing inverse dynamics, torque control, and sensor integration. An autonomous machine vision system will also be implemented and integrated with the robotic control systems.

Progress:
This grant is new in FY91.

TITLE: Conference on Neural Information Processing Systems - Natural and Synthetic

PRINCIPAL INVESTIGATOR: John Moody
Yale University
Department of Computer Science
(203) 432-1246

R&T PROJECT CODE: 4426053 CONTRACT NO: N0001491J1811

Objective:
The objective of this conference is to promote interdisciplinary research on neural networks involving engineering, mathematical and neuroscience approaches.

Approach:
The conference is held for 4 days in Denver with special oral and poster sessions, and publishers displays, followed by a 2 day intensive workshop at Keystone,CO. Topics presented include neuroscience, learning theory, complexity theory, VLSI and optical implementation of neural nets, algorithms, cognitive science and AI, speech processing, machine vision, and robotic control. The proceedings are published.

TITLE: Neural Network Models for Predicting Lapses in Vigilance from Brain Evoked Responses to Irrelevant Probes

PRINCIPAL INVESTIGATOR: Terrence J. Sejnowski
The Salk Institute
(619) 453-4100

R&T PROJECT CODE: 442h015 CONTRACT NO: N0001491J1674

Objective:
The objective is a vigilance monitoring system based upon sampling evoked potential signals from sonar operators, classifying those signals with a neural network paradigm, and, thereby be capable of continuously detecting changes in the probability of operator accuracy, with relatively few errors, yet not interfering with concentration on the task at hand.

Approach:
The human ERP data base will be provided by the Naval Health Research Center under the Biopsychometric Assessment Program (RS34H21) sponsored by ONT. In this grant, nonlinear estimation methods, based on neural network algorithms, will be used to examine these data. Later. new input variables (e.g. EEG spectral information and eye movement measurements) will be incorporated into the networks.

Progress:
This grant is new in FY91.

TITLE: Workshop in Computational Neuroscience

PRINCIPAL INVESTIGATOR: Terrence Sejnowski
Marine Biological Laboratory
(619) 453-4100

R&T PROJECT CODE: 4426818 CONTRACT NO: N0001491J1707

Objective:
Understanding the advantages and disadvantages of the use of computer modeling techniques in studying the nervous system will suggest possible mechanisms which in turn may be incorporated in hardware systems.

Approach:
The conference is being organized by the principal investigator aided by an organizing committee. The conference will be held in Woods Hole, MA. Workshop sessions will be held daily and will cover theoretical and experimental aspects of computational modeling with particular reference to the role of learning in sensory motor coordination.

TITLE: A Comparative Investigation of Neural Net Signal Processing Approaches for Detection and Classification

PRINCIPAL INVESTIGATOR: Manuel Solorzano
Naval Ocean Systems Center
(619) 553-9885

R&T PROJECT CODE: 442h100 CONTRACT NO: N0001491WX24106

Objective:
The objective is to develop and evaluate various combinations of signal preprocessors and neural net classifiers for reliable classification of helicopter gearbox faults from vibration sensor data.

Approach:
A simulation system will be constructed to test several time-frequency domain preprocessor techniques including Wigner-Ville, Choi-Williams, and wavelet transforms, using helicopter gearbox sensor data obtained from normal and faulty gearboxs. The output of the preprocessors will be classified by neural net classifiers including radial basis function nets, tree classifiers, and backpropagation nets.

Progress:
Backpropagation and probabilistic neural net classifiers prefaced with a principal component analysis filtered dataset properly classified fault vs. no-fault data with 100% accuracy, and was able to classify among six classes of fault with a very high accuracy.

TITLE: The Organization of Memory in Humans and Non-human Primates

PRINCIPAL INVESTIGATOR: Larry R. Squire
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Psychiatry Department
(714) 452-3330

R&T PROJECT CODE: 4426023 CONTRACT NO: N0001490J1454

Objective:
Work is directed towards understanding how memory is organized in the brain. Human studies will determine what kinds of procedural knowledge are acquired when learning occurs, how long it lasts, and how (if at all) such knowledge influences or otherwise interacts with conscious remembering. Primate experiments are directed towards defining a structure and physiological mechanisms which does not itself store memory but which serves to address, organize, or otherwise support memory storage sites for a limited period after learning.

Approach:
Two approaches will taken. The first involves cognitive testing of intact monkeys and monkeys given small neurosurgical lesions to damage or disconnect structures within the medial temporal region of the brain. The second involves studies on a population of 15 amnesic patients. Four separate experiments are proposed to address questions about 1) retrograde amnesia; 2) the nature of residual (declarative) learning ability in amnesia; 3) preserved skill learning in amnesia; and 4) preserved word priming in amnesia. Experiments 1 and 2 are designed to complement the monkey studies.

Progress:
PI developed new protocols using magnetic resonance imaging to precisely measure hippocampus and mammillary nuclei and thereby distinguish medial temporal lobe from diencephalic based amnesia.

Report:
Squire, L., Amaral, D. and Press, G. (1990, in press) Magnetic resonance measurements of hippocampal formation and mammillary nuclei distinguish medial temporal lobe and diencephalic amnesia. J. Neuroscience.

Squire, L. And Frambach, M. (1990). Cognitive skill learning in amnesia. Psychobiology, 18: 109-117.

TITLE: A Study of Neuronal Properties, Synaptic Plasticity and Network Interactions

PRINCIPAL INVESTIGATOR: David Tam
Baylor College of Medicine
Division of Neuroscience
(713) 798-3100

R&T PROJECT CODE: 4426400 CONTRACT NO: N0001490J1353

Objective:
The objective is to investigate principles of synaptic interactions, in particular the relation of membrane properties of neurons to synaptic plasticity in groups of interacting neurons, as the substrates of learning and memory.

Approach:
The approach is a combined theoretical and experimental analysis of the biophysical properties of hippocampal pyramidal neurons. Realistic simulations of these neurons will permit the study of changes in signal processing when membrane properties are changed. The emergent properties exhibited by groups of interacting neurons, with specific synaptic plasticity rules, will be examined in computer reconstructions. An enhanced software system for single neuron and neuronal network simulation will be developed. Experimental data from biological (slice) preparations will be used to verify model predictions.

Progress:
Computer models simulating the biophysical properties of neurons are being implemented on the Mac IIci computer. The coding of the neural simulator programs MacNeuron (a detailed biophysical simulation model of compartmental neurons) and MacNerveNet (a reduced system simulation model representing the integrate-and-fire characteristics of neurons for producing spike trains) have been initiated. The simulators are implemented in the object-oriented language Object Pascal since the codes are modular and can incorporate new biophysical properties without extensive rewriting of code.

Report:
Tam, DC (1990, in press) A hybrid time-shifted neural network for analyzing biological neuronal spike trains. Prog. in Neural Networks.

Tam, DC (1990) Decoding of firing intervals in a temporal-coded spike train using a topographically mapped neural network. Proc. IJCNN, 3, pp 627-632.

TITLE: A Biological Neural Network Analysis of Learning and Memory

PRINCIPAL INVESTIGATOR: Richard F. Thompson
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Psychology Department
(213) 743-2240

R&T PROJECT CODE: 4426001 CONTRACT NO: N0001491J1392

Objective:
The PI plans to model the critical neuronal circuitry in classical conditioning at several levels. Level I concentrates on single pathway models of conditioning involving the IO, deep nuclei, and other brain structures. These models will address phenomena at a trial-level of detail comparable to the Rescorla-Wagner model. Level II integrates level I into real-time models of conditioning which address effects of ISI manipulations and adaptive delay of the CR. Level III incorporates the previous levels into multiple-pathway models involving more complete descriptions of the stimulus- response pathways.

Approach:
Approach involves a detailed empirical characterization of the properties of the essential neurobiological network and a quantitative computational modeling of the network that incorporates all the known properties and constraints of the actual biological network.

Progress:
Interpositus lesions abolished both CR and UR elicited by Dorsal Accessory Olivary Nucleus, thus ruling out US activation of reflex afferents.

Report:
Tocco, G., Devgan, K.K., Hauge, S.A., Weiss, C., Baudry, M. and Thompson, R.F. (1991) Classical conditioning selectively increases AMPA/Quisqualate binding in rabbit hippocampus. Science, in press.

Gluck, M.A., Reifsnider, R. and Thompson, R.F. (1990) Adaptive signal processing and the cerebellum: models of classical conditioning and VOR adaptation. In M.A. Gluck and D.E. Rumelhart (Eds.) Neuroscience and Connectionist Models. New Jersey, Lawrence Erlbaum.

TITLE: Computer Simulation of Neural Systems

PRINCIPAL INVESTIGATOR: Thomas P. Vogl
Environmental Research Institute of Michigan
(703) 520-5250

R&T PROJECT CODE: 4426132 CONTRACT NO: N0001488K0659

Objective:
The technical objectives involve finding the answers to the following questions: (1) What are the roles of presynaptic, postsynaptic, and intraneural time delays in biological network performance and stability? (2) Which features of the biologic system are essential for the memory/recognition process and which are phylogenetic detritus? (3) What are the qualitative and quantitative differences between long- and short-term memory? (4) What is the role of changes in the membrane potential curves (membrane polarization) in the learning process? (5) What are the respective roles of pan-neurons vs. circum-synaptic membrane changes in the learning and recall processes? (6) What is the role of interlayer, particularly next-nearest-neighbor layer, connections in the performance of neural nets?

Approach:
Initially, efforts will focus on modelling the structure, neurochemistry, neurophysiology, and biophysics of the marine mollusc Hermissenda crassicornis with eventual extension to more complex, vertebrate systems. An essential feature of the proposed effort will be the close collaboration among neurophysiology and biophysics researchers at the National Institutes of Health (DHHS/NIH/NINCDS) and computer science and applied mathematics researchers at ERIM in all stages of the planning and execution of the research.

Progress:
1. Expansion of the ANN algorithm (DYSTAL) based on the Hermissenda model to include features derived from vertebrate neurobiology. 2.Refinement of the lumped parameter computer model of associative learning in Hermissenda.

Report:
Alkon, D., Vogl,T., Blackwell,K.T. (1991, in press) Artificial learning networks derived from biological neural systems. Neural Networks Vol.IV. V. Milutinovic, ed. Prentice Hall.

Alkon, D., Quek,F. and Vogl, T. (1989) Computer modelling of associative learning in Hermissenda. Advances in Neural Information Processing Systems Vol. 1. D. S. Touretzky, ed. Morgan Kaufman Publ.

TITLE: Analysis of Neural Network Issues; Temporal Pattern Recognition, Integration with Fuzzy Logic

PRINCIPAL INVESTIGATOR: Gregg Wilensky
R & D Associates
(213) 645-1122

R&T PROJECT CODE: a44f004 CONTRACT NO: N0001489C0257

Objective:
The objective is to explore the scaling issues of neural networks for both static pattern classification problems and the classification of temporally varying signals. Another objective is to assess the utility of combining neural networks with fuzzy logic.

Approach:
The approach will involve implementations of neural nets and assessing their ability to scale up for pattern classification tasks. An integrated fuzzy logic neural net will be developed to determine the probabilistic functions which minimize overall error on control and classification problems. The PI will collaborate with R. Granger (UCI) to explore the capabilities of a new temporal sequencing model based on neural dendrite properties. The performance of this model will be compared with other neural nets on test problems, and evaluated, based on code development time, speed of operation, learning rate, and performance of correct classifications. Neural net approaches will also be evaluated on an industrial process control problem.

Progress:
The contractor demonstrated the scaling properties of backpropagation to high dimensions in feature space for multi-dimensional Gaussian discrimination. He compared the performance of backpropagation with two conventional classifiers (nearest neighbors and Bayes) for simple image discrimination. He assessed the applicability and utility of several ANN architectures, including the Lynch-Granger net, and provided reports on the results.

Outside Funding:
Funds for this contract are provided by DARPA.

BIOLOGICAL INTELLIGENCE

SINGLE-NEURON COMPUTATION

TITLE: Theoretical and Experimental Determination of the Biological Mechanism of Retinal Directional Selectivity

PRINCIPAL INVESTIGATOR: Franklin R. Amthor
University of Alabama
Department of Psychology
(205) 934-3850

R&T PROJECT CODE: 4426610 CONTRACT NO: N0001491J1280

Objective:
The objective is to determine the computational algorithms and synaptic circuitry underlying sensitivity of retinal neurons to direction of motion of visual targets.

Approach:
The fundamental approach of the proposed research is to combine formal, theoretical analysis with physiology and quantitative anatomy. Theoretical tools for visual information processing, such as linear and nonlinear filtering based on two dimensional Fourier transforms of the visual stimulus will be explored in the modelling effort.

Progress:
This grant is new in FY91.

TITLE: Self-Organization of Hebbian Synapses on Hippocampal Neurons

PRINCIPAL INVESTIGATOR: Thomas H. Brown
Yale University
Department of Psychology
(202) 432-7009

R&T PROJECT CODE: 4426405 CONTRACT NO: N0001490J4136

Objective:
The objective is to discover the computational capabilities of single hippocampal neurons containing Hebbian synapses using realistic simulations based on data obtained by electrophysiology and anatomical imaging techniques.

Approach:
The general approach involves constructing model hippocampal neurons and then embedding them in environments that consist of different types of spatiotemporal correlations among the synaptic inputs. There will be continuous interaction between simulations and experimental analysis. Morphological data on neurons will be obtained by accurate 3-D reconstruction of dendritic surface from images obtained by confocal laser scan microscopy. Physiological data will be obtained by whole-cell patch clamp recording, and use of voltage or Ca++ sensitive dyes. Data will be incorporated in a detailed compartmental electrotonic model of single neurons, which will then be presented with different spatio-temporal patterns of synaptic input and the self-organization of representation of the input space explored for different variants of Hebbian synaptic plasticity.

Progress:
Morphometric data were obtained from 3-D reconstructions of hippocampal neurons. A model neuron with 300-400 compartments was simulated. The model included NMDA conductances on spines, and several thousand synapses. Randomly chosen small subsets of the synapses were activated synchronously, and membrane potentials were computed in each location in the dendritic tree. These voltages were used to compute synaptic weight changes according to a Hebb rule. Analysis of the spatial pattern of synaptic weights revealed a self-organization of clustered, strengthened synapses which terminated within a restricted electrotonic domain. The significance of this finding is that the electrotonic structure of the neuron is a primary constraint on the self-organization of biological networks.

Report:
Brown, T.H., Zador, A.M., and Claiborne, B. (1991) Hebbian computations in hippocampal dendrites and spines. In: Single Neuron Computation, T. McKenna, J. Davis & S. Zornetzer, (Eds.) Academic Press, NY.

TITLE: Diverse Computational Properties of Single Neurons in Neocortex

PRINCIPAL INVESTIGATOR: Barry W. Connors
Brown University
Division of Biology and Medicine
(401) 863-2982

R&T PROJECT CODE: 4426402 CONTRACT NO: N0001490J1701

Objective:
The objective is to examine quantitatively the computational properties of different types of single neocortical neurons.

Approach:
The approach is to record from single cortical neurons in vitro, subjected to a variety of standardized protocols to determine their firing patterns in response to specified inputs, and identify the neuron morphology by dye injection. The effects of the neuromodulators norepinephrine and acetylcholine on the transform properties of different types of neurons will be examined quantitatively. In order to test the hypothesis that different intrinsic input-output properties of single neurons are significant for network behavior, a formal model of a net of realistic model neurons will be developed. This study will explore the importance of intrinsic neuronal properties in biological models of neocortex.

Progress:
Patch-clamp electrophysiological recording on superficial and deep neocortical neurons in vitro has begun. The recording data are being combined with anatomical data by biocytin staining with neuron reconstruction, and compartmental modelling. A Sun Sparcstation has been acquired, and neuron data are being modelled using the NEURON program. Preliminary results indicate that GABAergic inhibitory interneurons are more electronically compact than pyramidal neurons. The GENESIS program is being implemented.

TITLE: Interneuronal Information Processing

PRINCIPAL INVESTIGATOR: Daniel Gardner
Cornell University Medical College
Department of Physiology and Biophysics
(212) 746-6373

R&T PROJECT CODE: 4426021 CONTRACT NO: N0001490J1460

Objective:
Project will identify and characterize types of functional elements available to an actual neural network, the ways in which they are combined, and the functional consequences of their use. The goal is both a generalizable biophysical description of synapses and an understanding of the role of the synapses in the adaptive behavior of a cell and network.

Approach:
The PI will develop mathematical models of the stochastic processes involved in heterosynaptic plasticity. The PI will test these models experimentally with intracellular recording, under voltage clamp conditions in buccal ganglia of aplysia.

Progress:
Analysis of neurotransmitter release at different terminals of the same presynaptic neuron, and at terminals of different presynaptic neurons converging upon the same postsynaptic is consistent with the view that the amount of presynaptic transmitter release is specified by the postsynaptic neuron that is being innervated.

Report:
Gardner, D. (1990) Paired individual and mean postsynaptic currents recorded in four-cell networks of Aplysia. J. Neurophysiol. 63: 1226-1240.

Gardner, D. (1989) Synaptic variability of four-cell networks in the buccal ganglia of Aplysia. Soc. for Neuroscience Abstracts, 15:184.

TITLE: Understanding Cortical Microcircuits: A Combined Anatomical, Physiological, Computational and Electronic Approach

PRINCIPAL INVESTIGATOR: Christof Koch
California Institute of Technology
Computation & Neural Systems Program
(818) 356-6855

R&T PROJECT CODE: 4426410 CONTRACT NO: N0001491J1452

Objective:
The objective is to specify the neuronal properties and connections of a basic cortical circuit that will exhibit some of the important visual response properties of real cortex, and to render this circuit in analog VLSI.

Approach:
Light and EM microscopic data will be used to reconstruct the detailed morphology of histologically labelled neurons in the visual cortex of cat. These reconstructions, and their associated physiological data, will provide the biological basis for realistic simulations. Detailed computer simulations based on solution of associated nonlinear cable and diffusion equations of these real neurons will be constructed. The dynamic properties of small microcircuits composed of small, upper layer pyramidal neurons, large, lower layer pyramidal neurons, and smooth dendrite inhibitory neurons, referred to as the "Canonical Microcircuit" will be investigated with sensory inputs. A range of CMOS VLSI subcircuits and networks, using pulse coding, will be designed and fabricated as powerful modelling tools for linking the receptive field and feature extraction properties of visual cortex with the real neuron microcircuitry.

Progress:
This grant is new in FY91.

TITLE: Understanding Cortical Microcircuits: A Combined Anatomical, Physiological, Computational and Electronic Approach

PRINCIPAL INVESTIGATOR: Kevan A. Martin
Medical Research Council
Department of Pharmacology
(0865) 275184

R&T PROJECT CODE: 4426411 CONTRACT NO: N0001491J1830

Objective:
The objective is to specify the neuronal properties and connections of a basic cortical circuit that will exhibit some of the important visual response properties of real cortex, and to render this circuit in analog VLSI.

Approach:
Light and EM microscopic data will be used to reconstruct the detailed morphology of histologically labelled neurons in the visual cortex of cat. These reconstructions, and their associated physiological data, will provide the biological basis for realistic simulations. Detailed computer simulations based on solution of associated nonlinear cable and diffusion equations of these real neurons will be constructed. The dynamic properties of small microcircuits composed of small, upper layer pyramidal neurons, large, lower layer pyramidal neurons, and smooth dendrite inhibitory neurons, referred to as the "Canonical Microcircuit" will be investigated with sensory inputs. A range of CMOS VLSI subcircuits and networks, using pulse coding, will be designed and fabricated as powerful modelling tools for linking the receptive field and feature extraction properties of visual cortex with the real neuron microcircuitry.

Progress:
This grant is new in FY91.

TITLE: Computational Capabilities of Hippocampal Neurons

PRINCIPAL INVESTIGATOR: John P. Miller
University of California, Berkeley
Department of Cell and Molecular Biology
(415) 642-9045

R&T PROJECT CODE: 4426403 CONTRACT NO: N0001490J1879

Objective:
The objective is to determine the computational capabilities of hippocampal neurons by creating realistic computer models of hippocampal neurons and their synapses.

Approach:
Realistic compartmental models of hippocampal neurons will be produced which represent neurons as a network of equivalent electrical circuits. The models will be based on functional reconstructions that combine both morphological and physiological characteristics of dendrites as well as biophysical representations of synapses. Three dimensional reconstructions of granule neurons will be produced with a computer-microscope digitization system. This system will be extended to utilize a high resolution confocal microscope. Accurate measurements of biophysical parameters, including the synaptic currents for NMDA and non-NMDA synapses will be obtained from patch-clamp recordings. The model neurons will serve as the basis of a set of experiments on self-organization of dendritic function. This research is a collaboration of J. Miller at UC-Berkeley and Brenda Claiborne at U. Texas-San Antonio. It is complementary to research conducted by Thomas Brown at Yale, supported by a separate grant.

Progress:
In the initial 3 months software modifications have been performed to port programs from IBM RISC computers to SUN computers, and new fluorescent dye protocols and anatomical construction procedures developed which will permit utilization of confocal microscopy for 3-D neuron reconstructions.

TITLE: Role of Spatially Distributed Ion Channels in Single Neuron Computations

PRINCIPAL INVESTIGATOR: Peter C. Schwindt
University of Washington
Department of Physiology and Biophysics
(206) 543-6310

R&T PROJECT CODE: 4426401 CONTRACT NO: N0001490J1627

Objective:
The technical objective is to gain a detailed understanding of the computational ability of a single cortical neuron.

Approach:
Single neuron computation is likely to depend in part on the properties of voltage-gated channels located on the dendritic membrane. Such channels are known to exist, and are thought to be important in neural function, but almost no information is available on their precise spatial distribution or electrical properties. The investigators propose to measure the spatial distribution and electrical properties of specific ion channels in the soma-dendritic region of cortical neurons. Based on these measurements, a mathematical, computer-based model of a cortical neuron will be constructed and analyzed to determine how the spatially distributed channels affect information transfer through the neuron.

Progress:
The PI has been developing experimental procedures for localizing Ca++ channels at the EM level on neurons. Acutely dissociated cortical neurons are being used both for the development of ion channel labelling techniques using colloidal gold-tagged antibodies and electrophysiological characterization of whole cell Ca++ currents and their pharmacology. Techniques have been developed for obtaining kinetic data required for empirical modeling of specific ion currents.

Report:
Westenbroek, R.E, Ahlijanian, M.K. and Catterall, W.A. (1990, in press) L-type calcium channels are clustered at the base of major dendrites in hippocampal neurons. Nature.

Sayer, R.J., Schwindt, P.C. and Crill, W.E. (1990, in press) High- and low-threshold calcium currents in neurons acutely isolated from rat sensorimotor cortex. Neuroscience Letters.

TITLE: The Role of Dendritic Excitability in Processing Synaptic Inputs: A Combined Physiological, Morphological and Computational Study

PRINCIPAL INVESTIGATOR: Idan Segev
Hebrew University
Department of Neurobiology
(617) 253-2581

R&T PROJECT CODE: 4426406 CONTRACT NO: N0001491J1350

Objective:
The objective is to elucidate the basic principles that govern the integrative functions of the dendrites of cerebellar Purkinje neurons.

Approach:
A combined modeling and experimental study of Purkinje cells will be conducted. Real morphological and biophysical parameters will be incorporated into realistic, large scale simulations of individual neurons and the models predictions will be tested by in vitro physiological experiments. The simulations will be enhanced by the development of new flexible algorithms which will permit modeling large numbers of realistic dendritic spine compartments. Multiple synaptic inputs will be examined in vitro by electrical stimulation or iontophoresis of neurotransmitters.

Progress:
This grant is new in FY91.

TITLE: Data Base Acquisition for Computational Modeling

PRINCIPAL INVESTIGATOR: Allen I. Selverston
University of California, San Diego
Department of Biology
(619) 534-2672

R&T PROJECT CODE: 4426128 CONTRACT NO: N0001491J1720

Objective:
The goals of the proposed research are to obtain physiological data from an invertebrate nervous systems which can be used to support the development of new computational models of neural functioning. These can serve as the basis for pattern recognition and motor control algorithms. Data will be obtained relating the various conductances present in single neurons to their individual information handling capabilities. Additional information will be obtained on synaptic and network properties which could be used in modelling the system. As data are obtained, they will be incorporated into new computational models which will then be tested with experimental preparations.

Approach:
The model consists of only thirty neurons yet generates two complex output patterns. Moreover, these neurons are individually identifiable and their pattern of synaptic connectivity is stereotyped and well characterized. The behavior of the entire system can be altered by injecting current into single cells or by the application of various neuromodulators which alter synaptic strengths. This model system is perhaps the best understood biological pattern generator and is well-suited to a quantitative analysis.

Progress:
Rowat and Selverston describe connectionist learning algorithms for fully recurrent artificial networks can be generalized to provide a technique for parameter adjustment in a biological neural network. Turrigiano & Selverston describe a CCK-like neuromodulatory peptide capable of modifying neural circuitry.

Report:
Rowat, P. & Selverston, A. (1991, in press) Learning algorithms for oscillatory networks with gap junctions and membrane currents. Network.

Turrigiano, G. & Selverston, A. (1991, in press) Distribution of CCK-like immono-reactivity within the stomatogastric nervous system. Journal of Comparative Neurology.

TITLE: Dendritic Properties and Neural Networks.

PRINCIPAL INVESTIGATOR: Gordon Shepherd
Yale University
School of Medicine
(203) 785-4336

R&T PROJECT CODE: 442h001 CONTRACT NO: N0001489J1603

Objective:
The objectives are to identify the essential features of cortical dendrites and microcircuits and to incorporate them into more realistic models of cortical function.

Approach:
Using compartmental modelling techniques, the PI will pursue analysis of logic operations inherent in intradendritic communication signals. He will develop a basic cortical circuit in parallel with experimental studies in cortical slices obtained as routine biopsies in neurosurgical operations. Since the cortex and thalamus form a functional unit, he will develop a computational model for the thalamus, and integrate this with the cortical basic circuit.

Progress:
PI recorded first M/T cells that generate "opponent odor" responses to enhance grouping and discrimination. Described computation based neural network model simulating entire sequence of molecular information processing from olfactory receptor to cortical representation.

Report:
Shepherd,G. (1990) The significance of real neuron architectures for neural network simulations. Computational Neuroscience, ed. E.L. Schwartz, MIT Press, 82-96.

Shepherd,G. (1991, in press). Computational structure in the nervous system. Olfaction as a Model System for Computational Neuroscience, ed. J.L. Davis and H. Eichenbaum, MIT Press.

TITLE: Implications of Dendritic Models for Neural Network Properties

PRINCIPAL INVESTIGATOR: L. M. Simmons
Santa Fe Institute
(505) 984-8800

R&T PROJECT CODE: 4426051 CONTRACT NO: N0001491J1717

Objective:
The objective of this workshop is to address the question: What richness of network properties can one expect to gain from replacing binary network units with more realistic neuron models?

Approach:
This meeting will consist of formal paper presentations followed by extensive informal discussions in depth of the research results, new experiments, new computational approaches, and new collaborations.

TITLE: Cellular Mechanisms of Long-Term Depression of Synaptic Transmission and It's Role in Memory Systems

PRINCIPAL INVESTIGATOR: Patric K. Stanton
Albert Einstein College of Medicine
Department of Neuroscience
(212) 430-2574

R&T PROJECT CODE: 400x080 CONTRACT NO: N0001490J1988

Objective:
The objective is to determine the rules and mechanisms of synaptic changes during learning. Specifically, the rules governing induction of long-term depression of synaptic strength in hippocampus, and the receptor types regulating these changes will be identified. The long-term objective is to incorporate the rules for associative interactions that regulate synaptic strength into models of hippocampal function in order to generate predictions about the behavioral consequences of long-term plasticity.

Approach:
The rules and mechanisms governing synaptic plasticity will be examined in hippocampal slices. The timing rules for induction of LTD and LTP will be examined by varying the phase relation between inputs. The relative duration and decay of LTD and LTP will be compared. The receptor mechanisms of LTD will be examined by applying antagonists such as AP3 and obtaining dose-response relations. Intracellular recordings will be obtained to examine the role of postsynapic potentials in LTD. The link of LTD to behavioral learning will be examined by establishing the cellular mechanisms of action of agents which block delayed trace conditioning.

Progress:
PI identified a novel glutamate receptor subtype involved in LTD induction in hippocampus and neocortex. The receptor is activated by glutamate and quisqualate, and appears to be linked via a G-protein to the stimulation of phophatidylinositol hydrolysis.

Report:
Stanton, P.K. (1991) Phasic stimulus patterns controlling LTP and depression of synaptic strength in the hippocampus, In: Kindling and Neuronal Plasticity, F. Morrel (Ed) Birkhauser, Boston.

Haring, R., Stanton, P., Scheidler, M., and Moskal, J. (1991) lycine-like modulation of NMDA receptors by a monoclonal antibody that enhances LTP. Journal of Neurochemistry (in press).

BIOLOGICAL INTELLIGENCE

CHEMICAL MODULATORS OF INFORMATION PROCESSING

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TITLE: Chemical Sensor for Microscopic Mapping of Synaptic Glutamate

PRINCIPAL INVESTIGATOR: Mark A. Arnold
University of Iowa
Department of Chemistry
(319) 335-1368

R&T PROJECT CODE: 4426268 CONTRACT NO: N0001491J1768

Objective:
To develop an analytical methodology capable of measuring in situ levels of neurotransmitters in small regions of the extracellular space in the vicinity of the synapse during neurochemical events. Primary considerations are selectivity, detection limit, spatial and temporal resolution.

Approach:
A biocatalytic-chemiluminescence reaction will be measured using an optical microscope in conjunction with a photon-counting photomultiplier (later a CCD). Efficiency of detection optics, kinetics of the reaction sequence, and mass transfer properties of the chemical species involved interrelate to control the detection limit, temporal, and spatial resolution of the method.

Progress:
This grant is new in FY91.

TITLE: Synaptic Plasticity: Neural and Molecular Approaches

PRINCIPAL INVESTIGATOR: Michel Baudry
University of Southern California
Department of Biological Sciences
(213) 740-7762

R&T PROJECT CODE: 4426267 CONTRACT NO: N0001491J1821

Objective:
Using 3H-MK-801 as a marker for functional NMDA receptors and microdissection and quantitative autoradiographic techniques, determine the extent and localization of activated NMDA receptors under conditions leading to LTP in hippocampus, and determine the distribution of activated NMDA receptors in various behavioral paradigms measuring memory capacity.

Approach:
The approach takes advantage of a labeled ligand that tags functional NMDA receptors to study the relationships between learning and the in situ functioning of NMDA receptors. 3H-MK-801 labels the open state of the Ca channel associated with NMDA and LTP. Learning paradigms include; inhibitory avoidance, Y-maze discrimination, and one-trial olfactory learning.

Progress:
This grant is new in FY91.

TITLE: Synaptic Plasticity: Neural and Molecular Approaches

PRINCIPAL INVESTIGATOR: Michel Baudry
University of Southern California
Department of Biological Sciences
(213) 740-7762

R&T PROJECT CODE: 4426054 CONTRACT NO: N0001491J1796

Objective:
The objective of this conference is to bring together a select group of scientists in synaptic plasticity, including experts in molecular, cellular, behavioral and theoretical neurobiology in order to build bridges in the research efforts across these levels of analysis.

Approach:
This conference will last for 4 days. The 1st day will have presentations and discussion of molecular and cellular studies of synaptic plasticity, the 2nd day will be devoted to the topic of molecular and cellular studies of LTP, the 3rd day will examine both the molecular and cellular studies of LTD (Long Term Depression) and computational studies of learning and memory, and the final day will be on behavioral studies of learning and memory.

TITLE: Gordon Research Conference on Neural Plasticity

PRINCIPAL INVESTIGATOR: Alexander M. Cruickshank
Gordon Research Conference
University of Rhode Island
(401) 783-4011

R&T PROJECT CODE: 4426819 CONTRACT NO: N0001491J1687

Objective:
Objective of the conference is to further develop understanding of the mechanisms underlying neuronal plasticity.

Approach:
The conference is being organized by the principal investigator aided by an organizing committee. The conference will be held in Wolfeboro, NH. Daily sessions will cover various aspects of neural plasticity at the molecular, cell, and system level.

TITLE: Glucose Effects on Human Memory and on Neurobiological Memory Substrates

PRINCIPAL INVESTIGATOR: Paul E. Gold
University of Virginia
Department of Psychology
(804) 924-0685

R&T PROJECT CODE: 4426140 CONTRACT NO: N0001489J1216

Objective:
The work will assess pharmacological approaches to enhance memory in humans. The proposed studies will be performed on healthy young adult volunteers and will examine dose-response curves, several memory tasks, and questions of storage vs. retrieval.

Approach:
The PI will test the possibility that glucose injections, including peripheral, central, and very localized injections, can control the establishment of long-term potentiation at both the physiological and structural levels; and evaluate the effects of glucose on human memory.

Progress:
PI provided evidence for his hypothesis that peripheral hormonal influences on memory and motor behaviors are mediated by a central system including opiate inhibition of cholinergic function.

Report:
Stone, W., Walser, B., Gold, S.and Gold, P. (1991, in press) Scopolamine- and morphine-induced impairments of spontaneous alternation behavior in mice: reversal with glucose and cholinergic and adrenergic antagonists. Behavioral Neuroscience, 105.

Stone, W., Rudd, R. and Gold, P. (1991, in press) Glucose and physostigmine effects on morphine- and amphetamine- induced increases in locomoter activity in mice. Behavioral and Neural Biology.

TITLE: The Role of Lamination in Neocortical Function

PRINCIPAL INVESTIGATOR: Harvey J. Karten
University of California, San Diego
School of Medicine
(619) 534-4938

R&T PROJECT CODE: 4426131 CONTRACT NO: N0001488K0504

Objective:
A major goal of this project is to investigate the nature and benefits of lamination of cortex. In the avain brain, cortical equivalent populations ("clonal clusters") of neurons occur in non-laminated configurations, but have similar characteristics in their connections, transmitters and cell morphology. The clonal nature of the avain telencephalon lends itself to both physiological and biochemical analyses not readily accomplished with mammalian neocortex. In the proposed experiments, the PI will collect detailed information about the clonal type of organization, particularly, within the avian visual system.

Approach:
(1) The anterograde and retrograde transport of several tracers will be used to explore the microcircuitry of cortical equivalent neurons in the absence of lamination. (2) The transmitters/ peptides/receptors in these cortical equivalent populations will be studied using immunochemistry and in situ hybridization histochemistry. (3) The morphological characteristics of neurons in these populations will be studied using the single-cell filling technique.

Progress:
A detailed immunohistochemical study of visual "wulst" (equivalent to mammalian visual striate cortex).Described the existence of two parallel auditory streams ascending through the avian forebrain.

Report:
Shimizu, T. and Karten, H.J. (1990, in press) Immunohistochemical analysis of the visual wulst of the pigeon. J. of Comparative Neuroanatomy.

Shimizu,T. and Karten, H.J. (1990, in press) Multiple origins of neocortex: contributions of the dorsal ventricular ridge. In B. Finlay, H. Scheik, and G. Innocenti (eds) Ontogeny and Phylogeny of the Neocortex. NATO Conf.

TITLE: Analysis of Neural Systems Involved in Modulation of Memory Storage.

PRINCIPAL INVESTIGATOR: James L. McGaugh
University of California, Irvine
Department of Psychobiology
(714) 856-5401

R&T PROJECT CODE: 4426815 CONTRACT NO: N0001490J1626

Objective:
The objective is to increase understanding of the brain systems involved in the processing of newly acquired information, and of the key brain structures and processes underlying the modulation of memory storage.

Approach:
Two different pharmacologically defined neural systems will be examined using behavioral and neurochemical techniques to more precisely define the mechanisms responsible for their distinctive memoric processes.

Progress:
PI demonstrated that function of neuromodulatory systems in learning varies with the task requirement, e.g. aversively-motivated learning is mediated by amygdaloid complex and treatments affecting spatial learning work through septo-hippocampal system.

Report:
Liang, K., McGaugh, J. and Yao, H. (1990) Involvement of amygdala pathways in the influence of posttraining amygdala norepinephrine and peripheral epinephrine on memory storage. Brain Research, 508:225-233.

McGaugh,J. (1990) Significance and rememberance: the role of neuromodulatory systems. Psychological Science, 1: 15-25.

TITLE: Fourth Conference on the Neurobiology of Learning and Memory

PRINCIPAL INVESTIGATOR: James L. McGaugh
University of California, Irvine
Center for the Neurobiology of Learning and Memory
(714) 856-5193

R&T PROJECT CODE: 4426315 CONTRACT NO: N0001490J4008

Objective:
The conference participants will examine the locus of alterations in brain activity at three levels of organization: global cerebral function, specific systems, cellular and molecular mechanisms. The proceedings will be published.

Approach:
The contractors anticipate an international participation of 350 scientists including university faculty, postdocs, graduate students and from diverse institutions including government, private, industrial and academic laboratories. The proceedings will be published.

BIOLOGICAL INTELLIGENCE

NEURAL PROCESSING OF SENSORY INFORMATION

TITLE: Enhanced Testing of High Order Neural Networks for Sonar Signal Discrimination

PRINCIPAL INVESTIGATOR: Dennis J. Adams
Loral Defense Systems
(216) 796-2846

R&T PROJECT CODE: a44b002 CONTRACT NO: N0001489C0288

Objective:
Development and performance evaluation of adaptive, hybrid high order neural nets using signal processing functions optimized for extracting unique features of acoustic transients. This research will lead to the development of hierarchical neural net signal processing architectures optimized for classifying acoustic transients.

Approach:
The research approach is to first examine several unconventional signal processing functions (eg. generalized Fourier transforms such as Fourier Bessel or Fourier Laguerre transforms, maximum entropy methods, or fractal dimension estimators). This signal processing is designed to form new representations of the input signal which emphasize features that distinguish specific acoustic transients, while remaining relatively immune to variations due to source and propagating path inconsistencies. The output of this preprocessing would then be input to a set of high order neural nets (functional-link nets). These nets will be used for both supervised and unsupervised learning to discover the best representation for each transient type. Once this signal representation has been determined, a hierarchical, hybrid system will use these neural nets to process the data provided by DARPA and ONR, and classify the acoustic transients within the data.

Progress:
The contractor successfully analyzed STDS-1 data using a hybrid system which combined preprocessing (FFT, Maximum Entropy, Fractal processing or cross-power spectrum) into a sequence short term features which were provided to a higher order neural net. A very high performance (>90%) classification rate was achieved using this approach. Analysis of STDS-2 has begun.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Spatial Coding by Posterior Parietal Neurons

PRINCIPAL INVESTIGATOR: Richard A. Andersen
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
(617) 253-5773

R&T PROJECT CODE: 442g004 CONTRACT NO: N0001489J1236

Objective:
The objective is to deduce the coding of coordinate transformations in parietal cortex. A long standing question regarding the source of the eye position signal will be addressed by determining experimentally whether it is derived from efference copy or proprioceptive inputs. Computational models will be made progressively more complex by adding circuit details of known brain structures.

Approach:
A combination of physiological and computational techniques will be used in a series of experiments to pursue the question of how spatial transformations are accomplished in the posterior parietal cortex. The first series of experiments will determine whether head as well as eye position signals gate the visual responses of area 7a neurons, thus producing a coding for location in body-centered as well as head-centered coordinates. The second series of experiments will involve studies of 2-dimensional spatial tuning to examine the third dimension of depth by testing cells for vergence and disparity signals.

Progress:
Single posterior parietal cells never have receptive fields for restricted locations in head-centered space independent of eye position, suggesting code for spatial location is distributed. Therefore the search for single neurons with receptive fields for small regions of head-centered or body-centered space may be futile.

Report:
Andersen, R., Bracewell, M., Barash, S., Gnadt, J. and Fogassi, L. (1990) Eye position effects on visual, memory, and saccade-related activity in areas LIP and 7a of macaque. J.Neurophysiol. 10 (4):1176-1196.

Goodman, S.J. & Andersen, RA. (1990) Algorithm programmed by a neural network model for coordinate transformation. IJCNN Mtg. San Diego.

TITLE: Neural Networks for Real-Time Sensory Data Processing and Sensorimotor Control

PRINCIPAL INVESTIGATOR: Randall D. Beer
Case Western Reserve University
Departments of Computer Engineering & Science
(216) 368-2816

R&T PROJECT CODE: 4426420 CONTRACT NO: N0001490J1545

Objective:
The objective of the proposed research is to elucidate the principles by which invertebrate nervous systems control locomotion behavior, and to apply this understanding to the design of more autonomous, flexible, and robust hexapod robots.

Approach:
A detailed computer model of the neural circuitry and periphery (plant) involved in the cockroach escape response will be developed. This simulation will provide an interactive medium for synthesizing results of experimental and theoretical tests of system operation. In order to demonstrate that biological control principles can be applied to robotic design, the grantees will also construct a hexapod robot, and a locomotion controller based upon a neural model under development.

Progress:
1. Experimental Work: A quantitative analysis of insect leg movements has been undertaken using an NAC high speed video and computer motion analysis system. A description of the movements that occur at each joint of the leg during turns in response to wind relative to body angle has been obtained. Currently the movements of specific joints are being translated into activity in specific muscles. 2. Modeling and Simulation: An original simulation system using an interactive command-line interface with graphical tools has been implemented in C and X on a DEC 3100, and a 3-D kinematic model of the insect's body has been developed for the escape response. 3. Robotics: A hexapod robot has been designed, and the locomotion controller has been ported to a PC. This will allow the simulated controller to directly drive the robot during "debugging".

TITLE: Correlating Stimulus and Response Transformations in a Robotic Perceptual Motor System

PRINCIPAL INVESTIGATOR: Michael Blackburn
Naval Ocean Systems Center
(619) 553-1904

R&T PROJECT CODE: 4426323 CONTRACT NO: N0001491WX24148

Objective:
The project will study mechanisms for performing transformations on a response vector given different transformations of the target (perceptual constancy). This constancy will be achieved via greater emulation of known biological mechanisms, mapping of algorithms to a computer for real-time parallel processing and the integration of visual and effector systems.

Approach:
In cooperation with Abby Westerman at NOSC, who has demonstrated adaptive control of the NOSC manipulator arm in a 2-D reaching task, the PI will develop control algorithms (to be transputer implemented) that can be adapted to learn mappings of input from potentiometers and cameras monitoring joint angles and target location.

Progress:
This grant is new in FY91.

TITLE: Mechanisms Underlying the Generation and Coordination of Oscillatory Neuronal Responses in Cat Visual Cortex

PRINCIPAL INVESTIGATOR: Charles M. Gray
The Salk Institute
Vision Center Laboratory
(619) 453-4100

R&T PROJECT CODE: 4426321 CONTRACT NO: N0001491J1256

Objective:
The objectives of the proposed research are to provide answers to these two questions: 1) Do oscillatory neuronal responses recorded in spatially separate locations of the visual cortex, selectively synchronize when stimulated by the coherent motion of the contours of a discrete visual object? 2) What mechanisms underlie generation of neuronal oscillations and the coordination of this activity within separate locations of visual cortex?

Approach:
The PI will conduct neurophysiological experiments in cats in close conjunction with realistic neuronal network simulations of the visual cortex. Data gathering and simulations will target three specific hypotheses for mechanisms thought to underlie the generation of oscillatory responses.

Progress:
This grant is new in FY91.

TITLE: Neural Networks and Robotics Applied to the Nondestructive Inspection of Aircraft

PRINCIPAL INVESTIGATOR: Dan Greenwood
Netrologic Inc.
(619) 587-0970

R&T PROJECT CODE: 400e131 CONTRACT NO: N0001491C0095

Objective:
Netrologic will apply new methods in pattern recognition using neural networks to investigate rivet inspection techniques on a mobile robotic deriveter.

Approach:
NETROLOGIC will capitalize on its research programs in applying neural networks to problems in pattern recognition. Although crack recognition using eddy-current sensor data as input is the main technical goal, alternate sensors (e.g. ultrasonic, X-ray) will be examined along with various neural networks for recognition.

Progress:
This contract is new in FY91.

TITLE: Research on Artificial Neural Network Methods and Applications

PRINCIPAL INVESTIGATOR: Morgan K. Grover
Defense Group Inc.
(213) 394-8599

R&T PROJECT CODE: a44f006 CONTRACT NO: N0001489C0175

Objective:
The objectives of the research are: (1) to define and technically characterize a range of important DoD sensor and communications signal processing functions which could be enhanced by emerging neural net technologies, (2) to conduct digital simulations of specific applications, and (3) to identify potential hardware methods and additional neural net research needed for full-scale implementation.

Approach:
A comprehensive data base will be developed of priority DoD missions in pre-output signal processing which might be enhanced by neural net methods. These applications will be taken from the areas of: (1) digital communications, (2) radar sensors, (3) sonar sensors, (4) laser systems, and (5) passive optical systems. Two important applications will be selected, one in communications, and one in sensor systems. For these applications digital simulations will be conducted using multilayer neural networks appropriate for the application, including training sequences, evaluation of error rates, retraining after system perturbation, and comparison with alternative training procedures. Based upon these results probable neural network architectures will be defined in greater detail, including quantitative estimates of network size and speed, and potential approaches for hardware implementation identified.

Progress:
The investigator performed an analysis of the detailed performance of 8 contractors on a sonar classification task. These contractors were using various combinations of preprocessors and neural nets. He provided a report on this analysis which served to guide the development of further sonar datasets and procedures for quantifying classifier performance. He proposed new methods for improving ASW surveillance by the correlation of data from single or multiple sources in order to calculate tracks.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Demonstration of Neural Network Performance for On-Line Health Monitoring and Inspection of Aircraft

PRINCIPAL INVESTIGATOR: Gail A. Hickman
Innovative Dynamics
(607) 257-0534

R&T PROJECT CODE: 400e132 CONTRACT NO: N0001491C0094

Objective:
Innovative Dynamics proposes to implement neural network signal processing software on their aircraft Health Monitoring System (HMS) testbed. Structural abnormalities are determined via attached sensor arrays, distributed processors, and independent signal processing software modules. Neural networks will be compared with conventional classification algorithms in making decisions about the input.

Approach:
Extend research on HMS testbed by implementing neural network software for performance comparison with current pattern recognition system for monitoring/inspecting rivet line corrosion.

Progress:
This contract is new in FY91.

TITLE: Physiology, Anatomy, and Psychophysics of Parallel Processing in the Primate Visual Cortex.

PRINCIPAL INVESTIGATOR: David H. Hubel and Margaret Livingstone
Harvard Medical School
Department of Neurobiology
(617) 432-1664

R&T PROJECT CODE: 442g003 CONTRACT NO: N0001488K0200

Objective:
The first objective is to examine differences in responses between cortical layers in order to learn more about the transformation of information. The second objective is a detailed analysis of single cell properties in Visual Areas 1 and 2 as predicted from psychophysical experiments. The third objective is to continue studying the intrinsic connectivity among the three kinds of stripes in Visual Area 2. The fourth objective is to use voltage sensitive dyes to examine cortical column geometry in Visual Areas 1 and 2.

Approach:
To use anatomical tracer studies, physiological recordings, 2-deoxyglucose autoradiography and voltage-sensitive dyes to more clearly define which visual functions might be processed by each anatomically defined subsystem and to use psychophysical studies to explore how human visual perception correlates with the segregation and parallel processing seen in the physiological and anatomical studies in other primates.

Progress:
Showed cellular response differences between magno- and parvocellular divisions of visual system. In lateral geniculate these divisions are highly predictive of psychophysical results. Also, demonstrated replication of the Singer/Grey coherent oscillation data in cat.

Report:
Hubel,D. and Livingstone, M. (1990) Color and contrast sensitivity in the lateral geniculate and primary visual cortex of the macaque. J. of Neuroscience, 10, 2223-2237.

Livingstone, M., Drislane, F. and Galaburda, A. (1991, in press) Physiological evidence for a magnocellular defect in dyslexia. Science.

TITLE: Characterization of Ground Squirrel Retina Ganglion Cells

PRINCIPAL INVESTIGATOR: Nidza Lugo-Garcia
University of Puerto Rico
Medical Sciences Campus
(809) 721-4149

R&T PROJECT CODE: 4426205 CONTRACT NO: N0001489J3070

Objective:
Determine the retinal projection pathways in the central nervous system responsible for color vision. Such information may permit precise identification of the locus of visual system disorders.

Approach:
Conduct a series of experiments to characterize the dendritic arborization of cells projecting to different central nervous system areas, and determine if retinal ganglion cells project to more than a single target area.

Progress:
Rhodamine labeled microspheres were stereotaxically injected into both superior colliculi of five ground squirrels. Survival times ranged from ten days to two months, resulting in labeling of large numbers of retinal ganglion cells. Using electron microscopy, perikarya of different size ganglion cells can be easily recognized in longitudinal and transverse retinal sections. Immunoreactive neurons and fibers have been identified in the inner nuclear, inner plexiform and ganglion cell layer.

Report:
Lugo-Garcia, N., Blanco, R., Hughes, T., Karten, H. (1990) Localization of GAD-like and GABA -like immunoreactivity in the ground squirrel retina, Anatomical Record, 4: 60A.

TITLE: Modelling Temporal Dynamics in the Classification of Auditory Signals

PRINCIPAL INVESTIGATOR: Daniel Margoliash
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Anatomy Department
(312) 702-8090

R&T PROJECT CODE: 4426501 CONTRACT NO: N0001489J1509

Objective:
The objective of this research is the elucidation of the neural mechanism and algorithms used by animals to process auditory signals in order to provide critical insights for automating the classification of acoustic signals.

Approach:
The PI proposes to model both the recognition and production of song in oscine passerines (songbirds) and to test and modify these models in conjunction with ongoing neurophysiological and behavioral experiments. This is a well documented system for studying adaptive classification, and the PI has discovered forebrain areas with neurons which selectively respond to specific learned calls.

Progress:
Significant progress has been made in modeling the response properties of complex auditory neurons in the song system nucleus HVc. Model architectures have been explored using gradient descent methods to set model parameters to match properties of real neurons. These architectures use trainable feature detectors with limited temporal windows whose response across the duration of the stimulus is integrated by output units whose temporal response properties are also constrained. Architectures have been discovered which mimic real system neuron responses to artificial and natural stimuli. Ability of these architectures to generalize across song classes is currently being investigated.

Report:
Ulinski, P.S. and Margoliash, D.S. (1989) Neurobiology of the reptile-bird transition. In: Cerebral Cortex, vol. 8, Peters, A. and Jones, W.G. (Eds).

TITLE: Neural Networks: Comparative Performance Measurements

PRINCIPAL INVESTIGATOR: David J. Montana
Bolt, Beranek and Newman, Inc.
(617) 873-3000

R&T PROJECT CODE: a44d004 CONTRACT NO: N0001489C0264

Objective:
The objective is the comparative performance of two types of neural networks which have been iteratively tuned and optimized in the context of sonar signal classification.

Approach:
The contractor will implement backpropagation and genetic algorithm neural networks. The comparative performance of these nets applied to sonar acoustic transient classification will be examined for cases in which components of the networks are varied. These components include (a) node transfer functions, (b) optimization criterion, and (c) training procedures. The neural networks will operate directly from spectrally transformed data. The neural networks will be iteratively tuned for classification of acoustic transients. The performance of the nets will be compared with that of traditional sonar techniques and trained human operators.

Progress:
Dataset 1 was classified using a variety of neural nets including backpropagation, CART, KNN (Kth nearest neighbor), and PNN (probabilistic neural nets). On these data, the techniques were comparable with regard to test errors. However, PNN and KNN showed substantially shorter training times. Dataset 1 was judged to be insufficient for a critical comparison of accuracy of classification, and further efforts have been devoted to analysis of dataset II.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Workshop on Rhythmic Oscillations in Mammalian Cortex

PRINCIPAL INVESTIGATOR: Lynn Nadel
University of Arizona
Department of Psychology
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R&T PROJECT CODE: 4426142 CONTRACT NO: N0001491J1611

Objective:
The objective is fourfold: (1) to review the currently existing neurophysiology data; (2) to consider the perceptual/cognitive phenomena to which they are being applied; (3) to consider the kinds of computational models that have been developed within neuroscience and cognitive science that rest on these findings; and, (4) to analyze the mathematical and physiological basis of these oscillations.

Approach:
The approach involves holding a workshop at which proponents of various interest domains will be able to interact and share their data and models. At least 40% of the workshop time will be devoted to discussion, to facilitate the broadest possible interdisciplinary give-and-take.

TITLE: Neural Network Feature Extraction and Classification for Sonar Signals

PRINCIPAL INVESTIGATOR: Roger Pridham
Raytheon Company
(401) 847-8000

R&T PROJECT CODE: a44c001 CONTRACT NO: N0001489C0304

Objective:
The objective is to develop and evaluate hybrid nets using compound neural net and RCE nets which make optimum use of the features present in a set of acoustic transients, and to produce benchmarks of the performance of these nets, including cases in which modules use back-propagation algorithms instead of RCE algorithms.

Approach:
The approach includes preprocessing via Fourier transform of segmented raw acoustic signal to produce a spectogram that will be encoded by a series of overlapping windows in frequency and time domains. The windows on the spectrogram slide along the time domain as the signal evolves. The network architecture consists of (1) a hybrid subsystem consisting of a heuristic feature extractor, feature extraction net (RCE), compound classifier, and control loops from classifer back to feature extraction, and (2) an all neural net subsystem with an adaptive (unsupervised learning) feature extractor net, followed by an RCE classifier. The output of both the systems 1 and 2 will be combined at a controller stage to determine the classification of acoustic transients.

Progress:
Raytheon has completed analysis of STDS-1 and has begun analysis of STDS-2. They use an MLD (Wolcin) detector (Pd=.79 for set 1), followed by 40 different time-frequency features with are then reduced by a matrix reduction procedure. This procedure is suited to real world data, but was under-utilized in STDS-1. A compound neural net classifier and quadratic Bayesian classifier showed similar results on data set 1 but the CNN was somewhat better with the more challenging dataset 2. Pd ranged from 50 to 95 % correct over the range of features examined, and various learning and test trials.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Comparative Performance Measurements of Neural Network Nearest Matched Filters for Sonar Signal Classification

PRINCIPAL INVESTIGATOR: Patrick K. Simpson
General Dynamics Corporation
Electronics Division
(619) 573-2417

R&T PROJECT CODE: a44d003 CONTRACT NO: N0001489C0270

Objective:
The objective is to provide quantitative measures of the sonar signal classification performance of three different neural networks designed for spectro-temporal processing, and an evaluation of several alternative pre-processing techniques.

Approach:
Sonar signal classification performance will be evaluated for (a) the GDE1 fuzzy post-processed nearest matched filter neural net (an extension of Grossberg's avalanche net, and Hecht-Nielsens nearest matched filter), (b) the Viterbi net nearest matched filter (based on Gaussian classifiers and Hidden Markov Models), and (c) GDE2 on-line learing spatiotemporal pattern classifier (constructed from Kohonen's Learning Vector Quantization, and Grossberg's matched filters, temporal decay spatial activation nets, and adaptive resonance theory). Several alternative techniques for preprocessing the sonar transients into a suitable spectral estimation for the neural networks. These are: (1) fast Fourier transforms, (2) higher order zero crossings, and (3) adaptive noise cancellation by LMS or backpropagation. Performance measurements will be collected for each of the three nets, including false alarm rate. Development and operation time analysis will be performed for these applications.

Progress:
The contractor developed a GDE-1 nearest-matched-filter ANN acoustic signal classifier and trained and tested this system on STDS-1 data set. They also developed a GDE-2 on-line learning ANN spatio-temporal pattern classifier, a maximum entropy spectral estimation for feature extraction in noise, and a backpropagation adaptive FIR for noise cancellation. They have begun analysis of STDS-2 data set.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Comparative Sonar Signal Discrimination Performance Using Neural Network Techniques

PRINCIPAL INVESTIGATOR: James C. Solinsky
Science Applications International Corp.
Advanced Systems Division
(619) 546-6007

R&T PROJECT CODE: a44b001 CONTRACT NO: N0001489C0241

Objective:
The PI proposes to develop a hybrid approach to sonar acoustic transient classification. This involves (a) identifying the best transient screening and feature detection processors, and (b) the development of self-learning artificial neural network algorithms.

Approach:
The sonar data will consist of "biologics" and data provided by DARPA. The equipment includes SAIC's commercially available neural network simulator. The features extracted from acoustic transients are encoded in a feature vector in classification space. The SAIC neural net classifier can feed back to the event feature extractor to regulate the density of feature vectors or prune out feature value axes which are irrelevant. A subsequent stage of neural net algorithm to be examined shares some properties with the adaptive resonance theory (ART) of Grossberg.

Progress:
A technical report on the results of test tape No. 1 was completed. The results of this extensive analysis, in brief, indicated a superiority in performance of the SAIC SCA classifier over other NN and statistical classifiers. Performance ratios (Pdet/Pfa) varied across signal types, depending on percent training. Best Average performance (eg., 157) was in excess of Gross performance (41.1), with Total Pdet achieving values up to 87 percent with 2 percent Pfa. In general, it was found that adding classes to represent "clutter" will improve signal classification performance, but does not affect noise classification performance.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Synaptic Computations for Target Ranging in Biosonar

PRINCIPAL INVESTIGATOR: Nobuo Suga
Washington University
Department of Biology
(314) 889-6805

R&T PROJECT CODE: 4426502 CONTRACT NO: N0001490J1068

Objective:
The long term objective is to arrive at description of the neural mechanism for performing cross-correlation analysis of pulse and echo for range discrimination in an echolocating bat.

Approach:
The approach will be to describe the synaptic mechanisms underlying target ranging by delay-dependent multiplication in FM-FM combination sensitive neurons of the auditory cortex. Specifically, this will be examined in terms of (1) neural delays, (2) nonlinear multiplication and (3) determinants of delay tuning. The encoding of (4) target size will also be investigated. Specific hypotheses will be tested by the microiontophoretic application of neuroactive agents onto sites in the thalamus and cortex where these mechanisms are implemented. This will provide a direct test of computational mechanisms inferred from single-unit physiology, using behaviorally relevant stimuli.

Progress:
Application of the GABA-A antagonist bicuclline was found to dramatically increase the duration of faciliation and broaden the tuning of FM-FM neurons in the medial geniculate and auditory cortex. Hence, inhibition plays a role in sharpening facilitative delay tuning in the auditory cortex. The facilitative response (multiplication of response) of FM-FM neurons in MGB consists of two components: fast and slow. The NMDA receptor blocker APV abolishes the slow response but does not change the width of the delay-tuning curve.

Report:
Suga, N., Olsen, J.F., & Butman, J.A. (1990) Specialized subsystems for processing biologically important complex sounds: cross-correlation analysis for ranging in bat's brain. In: "The Brain", Cold Spring Harbor Symp. 55.

TITLE: Detection of Acoustic Motion by Passive Listening

PRINCIPAL INVESTIGATOR: Terry T. Takahashi
University of Oregon
Department of Biology
(503) 346-4544

R&T PROJECT CODE: 4426500 CONTRACT NO: N0001489J1582

Objective:
The objective is to derive baseline data regarding the sensitivity of neurons in the owl's auditory system to moving acoustic targets in the dark, so that the capabilities of the neuronal circuits may be modelled and simulated. By studying acoustic motion-detection, the PI will address the general issue of how incoming information is stored, and how that stored information influences the perception of future signals.

Approach:
The approach utilized in this research for the design and improvement of passive, acoustic, motion-detecting and target-tracking devices is to study a biological system that is specialized for non-visual predation. The barn owl is known to capture moving prey, in absolute darkness, using only its sense of hearing. The PI has proposed a systematic, neurophysiological analysis of acoustic motion-sensitivity in the auditory system.

Progress:
The PI has concentrated on the dichotic basis of motion-direction sensitivity in auditory neurons of the barn owl. Neurons in the midbrain of the owl were discovered which were sensitive to the direction in which an acoustic stimulus moved. Since the owl is known to determine the location of a sound-source based on the interaural differences in timing and intensity, the PI has been testing the motion-sensitive neurons with sounds having time-varying interaural time and intensity differences. These sounds have amplitude and phase modulations that simulate motion. Many of the neurons were observed to be sensitive to the direction of amplitude or phase modulation. A small number of neurons was found which prefer a moving stimulus to a stationary one.

Report:
Wagner,H. and T.T. Takahashi (1990) Neurons in midbrain of owl are sensitive to the direction of apparent acoustic motion.
Naturwissenschaften, 77, 439-442.

T.T. Takahashi and H. Wagner (1990) Directional sensitivity of auditory neurons in the owl. Neurosci. Abst., 16, 875.

TITLE: Optical Imaging of Neuronal Mechanisms for Visual Perception and Behavior

PRINCIPAL INVESTIGATOR: Daniel Y. Ts'o
Rockefeller University
(212) 570-7671

R&T PROJECT CODE: 400x095 CONTRACT NO: N0001491J1865

Objective:
First, to develop a new optical imaging procedure based on monitoring intrinsic brain voltages that will be compatible for use in awake, behaving primate studies. Second, to determine the mechanisms of preattentive and attentive visual search in primate visual cortex with the aid of optical imaging. Third, to observe changes in cortical activity patterns during the learning of a visual task.

Approach:
The new methodology involves acquiring frames by a host computer from a slow-scan CCD camera. These frames are images of the cortex illuminated by 630nm light. Near-infrared illumination may also be used due to the greater penetration of infrared light through tissue. Behavioral tasks will be performed with awake, restrained monkeys trained (and monitored) to maintain fixation in the visual field during stimulus presentation. Matching-to-sample, eye saccade responses, and reaction time measurement briefly describe the behavioral approach.

Progress:
This grant is new in FY91.

TITLE: Comparative Performance Measurements for Continuous Speech Recognition by Neural Networks

PRINCIPAL INVESTIGATOR: Alex Waibel
Carnegie-Mellon University
School of Computer Science
(412) 268-7676

R&T PROJECT CODE: a44b004 CONTRACT NO: N0001491J1131

Objective:
The objective of this research is to develop a continuous speech recognition system that uses artificial neural networks, and compare its performance with systems based on other techniques.

Approach:
Linked modules of Time-Delay Neural Networks will be extended for speaker-independent speech recognition at the acoustic/phonetic level, and hybrid neural and hidden Markov methods will be examined at the word level. The best use of connectionist (neural) and classical recognition techniques for speaker-independent large-vocabulary continuous speech will be evaluated using standard speech databases.

Progress:
The PI has implemented several connectionist and non-connectionist models in large vocabulary speech recognition systems and evaluated performance on a 400 word speaker dependent continuous speech recognition tasks. Best performance was achieved with a learning vector quantized based neural net hybrid. An extension of the time delay neural network that embeds the management of multiple sequential states has been achieved. This system was successfully tested on a spelling task, and outperformed the SPHINX system (based on AI techniques). The Meta-Pi network was shown to achieve some degree of speaker independence in a phoneme discrimination task.

Outside Funding:
Funds for this contract are provided by DARPA.

TITLE: Cortical Adaptive Filtering in Bioacoustic Signal Classification

PRINCIPAL INVESTIGATOR: Norman M. Weinberger
University of California, Irvine
Center for the Neurobiology of Learning and Memory
(714) 856-5512

R&T PROJECT CODE: 442m100 CONTRACT NO: N0001491J1193

Objective:
The objective is to determine the extent to which training-induced adaptive filtering in the auditory cortex can contribute to optimum acoustic signal classification.

Approach:
This research combines neurophysiological recording from auditory cortex with learning of acoustic discriminations in guinea pigs. The behavioral experiments have been designed to characterize adaptive filtering in the presence of noise, in the presence of target and non-target signals, sensitivity to context, and with complex acoustic signals. The paradigms and analysis of neuronal responses have been adapted to test specific models of signal classification in the auditory system developed by Richard Granger, based on his hierarchical neural classifier.

Progress:
This grant is new in FY91.

TITLE: Hybrid Classifier for Sonar Transient Signals

PRINCIPAL INVESTIGATOR: James W. Whiteley
Tracor Applied Sciences, Inc.
(512) 926-2800

R&T PROJECT CODE: a44d001 CONTRACT NO: N0001489C0298

Objective:
The goal of this research is to identify and evaluate artificial neural network architectures that are optimal for the adaptive classification of acoustic transients.

Approach:
The approach is to develop a hybrid classifier that integrates the best attributes of neural networks and conventional classifiers for sonar signal classification. Innovative aspects of the approach are: (1) establishment of a parametrized set of optimal features by investigation of the application of higher order spectra and image processing methods to sonar signal feature extraction; (2) the development of a time delay neural network that is matched to time varying features of transients; (3) the use of internal representations and projective fields of neural networks to identify novel discriminators; (4) the use of pre-encoded information from conventional classifiers to speed neural network training; and (5) the synergistic interaction between neural networks, feature extractors, and conventional classifiers to iteratively drive toward an optimal classifier design.

Progress:
Tracor has completed analysis of STDS-1. They used various combinations of preprocessors: Gabor wavelets, AR coefficients, and short FFT together with neural net classifiers: backpropagation, radial basis functions, Kohonen or statistical classifiers: KNN and min. distance linear classifier. Pd ranged from 80 to 95%. When signal features were deleted, the most robust combination was wavelet transform followed by radial basis function neural net classifier (>92% Pd).

Outside Funding:
Funds for this contract are provided by DARPA.

BIOLOGICAL INTELLIGENCE

COMPUTATION IN OLFACTORY SYSTEMS

TITLE: Computational Theory and the Olfactory System

PRINCIPAL INVESTIGATOR: James M. Bower
California Institute of Technology
Division of Biology
(818) 356-6817

R&T PROJECT CODE: 4426136 CONTRACT NO: N0001491J1831

Objective:
The overall objective is to forge a link between the components of abstract neural network processing and the detailed anatomy and physiology of an actual neural system. This proposal links the more theoretical neural network models studied by Hopfield to the actual structural components of the olfactory system studied by Bower.

Approach:
This project will develop physiological techniques for recording neuronal activity in behaving animals (albino rats). Initially, this approach will involve recording simultaneously from numerous neurons in the mitral cell layer of the olfactory bulb while the animal is performing olfactory discrimination tasks. In these experiments, the primary objective will be to determine the nature of stimulus encoding in the olfactory system and the role of this encoding in learning and memory.

Progress:
Results have revealed new mechanisms for the generation and functional significance of oscillatory patterns for olfactory processing (Bower,1991). Also, associative memory capacity of the piriform cortex model was dependent on the presence of specific Hebb-type learning in the intrinsic fiber synapses (Hasselmo & Bower, 1991)

Report:
Bower, J. M. (1991, in press) Piriform cortex and olfactory object recognition. In: Olfaction as a Model System for Computational Neuroscience, Davis and Eichenbaum (Eds.)MIT Press, Cambridge, MA.

Hasselmo, M.E. and Bower, J. (1991) Afferent and association fiber differences in STP in piriform cortex. J. Neurophysiol. 64: 179-190.

TITLE: Nonlinear Neurodynamics of Biological Pattern Recognition

PRINCIPAL INVESTIGATOR: Walter J. Freeman
University of California, Berkeley
Department of Molecular & Cell Biology
(415) 642-0120

R&T PROJECT CODE: 4426318 CONTRACT NO: N0001490J4054

Objective:
The PI will develop, test and apply an instrument for pattern recognition which embodies the principles and algorithms that underlie this process in vertebrate cortex.

Approach:
By detailed inspection and analysis of experimental data, which the PI views as trajectories in 3-D and 4-D projections of the phase space of the dynamic system representing the cerebral cortex, he has developed a detailed model of the process of perception in the olfactory system. Earlier work from visual and somatosensory cortices suggests this model of perception holds true for all sensory systems. The PI will build a classification device based on these neural network principles.

Progress:
Equipment has been purchased and post-doc hired. Work progresses on implementing PIs olfactory bulb software in a 64-channel pattern recognizer.

Report:
Freeman, W.J. (1991, in press) Nonlinear dynamics in olfactory information processing. In: Olfaction as a Model System for Computational Neuroscience, J.L. Davis and H. Eichenbaum (Eds.). MIT Press.

TITLE: Computational Models of Olfactory and Spatial Cognition

PRINCIPAL INVESTIGATOR: Lynn Nadel
University of Arizona
Division of Neurobiology
(602) 621-6630

R&T PROJECT CODE: 442h025 CONTRACT NO: N0001490J1869

Objective:
A 48 element stereotrode array will be used to simultaneously record from about 150 differentiable cells in layer CA1 of the hippocampus as the rats perform a learned task involving their knowledge of spatial location. These data will be modelled and tested against a hypothesis that explains the process whereby the nervous system accomplishes this task.

Approach:
This work represents an empirical investigation of the Hebb-Marr hippocampal network theory using massively parallel recording from conscious animals. The PIs will determine whether the field potentials generated during exploration are specific to a given context (familiar vs unfamiliar) and whether these potentials change as the system stores information about new environments.

Progress:
PIs have purchased and integrated SUN work station (with peripherals) into present experimental system. Post-docs have been hired. Dr. McNaughton has completed move from Boulder.

Report:
McNaughton, B.L. and Nadel, L. (1990) Hebb-Marr networks and the neuro-biological representation of action in space. In: Neuroscience and Connectionist Theory. M. Gluck and D. Rumelhart (Eds.) Erlbaum Press.

Nadel, L. (1991, in press) Computation in the brain. In: Computers and the Brain. J. R. Brink (Ed.) Elsevier.

MANPOWER, PERSONNEL, AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

TITLE: Understanding and Enhancing Graphics Displays for Maintenance

PRINCIPAL INVESTIGATOR: William B. Rouse
Search Technology, Inc.
(404) 441-1457

R&T PROJECT CODE: 4428018 CONTRACT NO: N0001489C0047

Objective:
To provide research results that will provide guidance on concepts and principles for the presentation of graphical information to maintainers of complex systems and to test theories on the design of graphic information presentation for diagnostic problem-solving.

Approach:
Conduct formal experiments on: (a) the trainability of the concepts and principles underlying graphic displays at various levels of aggregation and abstraction during the maintenance of SH-3 helicopters; (b) the determination of the preferred types of display for those maintenance functions; (c) the display characteristics that influence transition among the various levels of aggregation; and (d) the influence of maintainer experience on the effectiveness of the graphic displays.

Progress:
The actions performed, strategies employed and diagrams used during maintenance of the bladefold system of the SH-3 helicopter were determined. Those data were used to design CRT graphic displays based on aggregation and abstraction principles. The effectiveness of those displays are being investigated in a series of experiments involving helicopter maintenance technicians.

Report:
Frey, P.F., Rouse, W. R. Garris R. D. (1990) Big Graphics and Little Screens: Designing Graphical Displays for Maintenance Tasks. Tech Rept STI-TR-8817-003, Norcross, GA: Search Technology, Inc.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

TITLE: Manpower Research and Advisory Services

PRINCIPAL INVESTIGATOR: H. W. Sinaiko
Smithsonian Institution
Manpower R&D Program
(202) 357-1829

R&T PROJECT CODE: 4428032 CONTRACT NO: N0001489C0093

Objective:
This contract provides for short-term research, expert consultation, and working groups to supplement contract research programs in cognitive and neural sciences. It provides quick reaction responses to research problems associated with manpower and personnel issues in naval operations.

Approach:
Continuing research support to the programs of the ONR Manpower R&D Committee is provided in such areas as computerized adaptive testing, human resources modeling, investigations of personnel attrition, retention and innovative training technologies.

Progress:
ONR principal investigators met at the National Academy of Sciences to review progress and to establish plans for the research initiative single neuron computation. Expert consultations were held to exchange in formation on recent advances in computational neuroscience, model-based psychological measurement, biopsychometrics, and distributed decision making.

Report:
Sinaiko, H. W. (1989) Technical Panel UTP-3, Military Human Resource Issues. Annual Rept. Washington, DC: The Technical Cooperation Program (TTCP).

Outside Funding:
Funds for this grant are provided by ONT, Code 222.

TITLE: Development of Intelligent, Computerized Aids for the Specification of Causal Models from Large Data Bases

PRINCIPAL INVESTIGATOR: Peter Spirtes
Carnegie-Mellon University
(412) 268-8571

R&T PROJECT CODE: 4428027 CONTRACT NO: N0001491J1361

Objective:
This project aims to develop reliable computerized methods of formulating "multiple indicator" causal models of datasets with large numbers of variables. These will be incorporated in the existing TETRAD II program of artificially intelligent aids to causal modeling of correlational data. The methods will be applied to Navy personnel record databases.

Approach:
In order to deal with large numbers of variables, variables will be clustered on substantive grounds and treated as indicators of a smaller number of latent variables. New heuristic search techniques will be developed to improve the capability of searching for plausible models of such more complex datasets. Graph theoretic techniques will be used to identify causal models which are not, in principle, distinguishable on the basis of the correlational data.

Progress:
The improved version of TETRAD II developed under the previous grant was shown to be very effective in helping researchers to search for alternative plausible models. The methods were applied in analyzing datasets concerned with understanding the causes of recruiter success and satisfaction and success among air traffic control trainees.

Report:
Spirtes, P., Scheines, R., & Glymour, C. (1990) Simulation studies of the reliability of computer-aided model specification using the TETRAD II, EQS, and LISREL programs. Sociological Methods and Research, 19, 3-66.

Spirtes, P., Glymour, C. & Scheines, R. (1990) Causality from probability. In: Evolving Knowledge in Natural Science and Artificial Intelligence. G. Mckee (Ed), Pittman.

Outside Funding:
Funds for this project are provided by ONT, Code 222 andd NPRDC.

TITLE: DATABASE EXPLORER: Large Scale Database Application

PRINCIPAL INVESTIGATOR: Jan M. Zytkow
Wichita State University
Department of Computer Science
(316) 689-3178

R&T PROJECT CODE: 4428028 CONTRACT NO: N0001491J1362

Objective:
The objective of this project is to build an automated aid for database exploration that will increase the scope and efficiency of the exploration and discovery that a human analyst can do, and to test the system by applying it to several databases to be provided by NPRDC.

Approach:
A prototype of the system will be built that is based on several existing systems for scientific discovery. The consolidation will aim at a clear modular architecture for the system, a uniform internal representation of goals and results, and at automation of exploration and discovery. It will be designed so that new methods can be introduced as additional modules and so that it can be adapted to different databases by modifying the specifications of domain knowledge and goals of search. Experimental applications will test the system and yield insight into the way that a human analyst can interact with the system. Iterative modifications and improvements are anticipated as a result.

Progress:
A software system has been implemented that consists of two parts, an explorer and a knowledge component that stores relevant knowledge about the database and the goals of the user and also allows the user to review the results of search. The system has been tested on an NPRDC training database and found many significant regularities. An interpretive module is being implemented which optimize the application of a regularity by taking into account the cost of actions and the expected improvements.

Report:
Zytkow, J.M. & Baker, J. Adapting FAHRENHEIT to an archival mode of operation: DB-49er tackles a database mining assignment. In: Knowledge Discovery in Databases, G. Piatetsky-Shapiro & W. Frawley, Eds., in press.

Outside Funding:
Funds for this project are provided by ONT, Code 222.

UNIVERSITY RESEARCH INITIATIVE: DECISION MAKING IN HIERARCHICAL TEAMS

TITLE: Effective Team Performance Under Stress and Normal Conditions

PRINCIPAL INVESTIGATOR: Daniel R. Ilgen
Michigan State University
Department of Psychology and Management
(517) 355-7503

R&T PROJECT CODE: uri5206-9002 CONTRACT NO: N0001490J1786

Objective:
The objective is to learn about modifiable factors in the selection of team members, in the design of team tasks, and in the training of team members that influence the effectiveness of team performance in decision making under conditions of uncertainty.

Approach:
Behavioral experiments will be conducted in which teams work on complex coordinated decision making tasks over extended periods of time. Time series analyses of team characteristics and performance will be done, taking into account the individual difference characteristics of team members, social factors within the group, and the cooperation and coordination requirements of the assigned tasks as variables. Stress will be manipulated by work overload and loss of normally available information.

Progress:
The needed laboratory facility has been established. The team decision making task has been programmed in a flexible way which will permit adaptation to a variety of team decision making situations with ease. Pilot groups have been run on the task and the software debugged. Materials to train subjects in the task have been developed, including a training manual along with a video training presentation. Over 3000 hours of subject data have now been collected in experiments with 4-person teams.

TITLE: Contingent Coordination in Naval Team Decision Making

PRINCIPAL INVESTIGATOR: David L. Kleinman
University of Connecticut
Dept. of Electrical & Systems Engineering
(203) 486-3066

R&T PROJECT CODE: uri5201-9002 CONTRACT NO: N0001490J1753

Objective:
The objective is to determine how hierarchically organized teams can most effectively coordinate their communication and action in response to varying time and workload stress and the availability of communications channels.

Approach:
Normative mathematical models of theoretically optimum behavior in these situations have been developed in previous work. An appropriate simulation of the decision making task environment has also been developed. In order to determine the relationship between this theoretical analysis and actual human behavior, behavioral experiments with 3 and 4 person teams will be conducted in the simulation environment. Time stress and workload will be varied, as will the availability of communication channels and the specified organizational structure dividing responsibilities among team members.

Progress:
A model-driven experiment on information coordination in 4-person hierarchical team has been completed and is currently under analysis and modeling. A second experiment that examines the adaptation of subordinates detection thresholds to their commanders' cost structure and information base is being run. An experiment has been completed on tasks requiring sequential cooperation by multiple (3) team members under different levels of leader involvement, time stress and communication structure.

Report:
Tang, Z.B., Pattipati, K.R. and Kleinman, D.L. (1991) Optimization of detection networks: Part I, tandem structures. IEEE Trans on Systems, Man, and Cybernetics.

TITLE: The Effects of Organizational Structure on Distributed Human Decision Making Under Uncertainty

PRINCIPAL INVESTIGATOR: Paul E. Lehner
George Mason University
Department of Systems Engineering
(703) 323-4355

R&T PROJECT CODE: uri5202-9002 CONTRACT NO: N0001490J1680

Objective:
The objective is to identify and characterize variables that enhance coordination of tactical decision-making teams and enable teams to maintain coordinated action under the stressful conditions characteristic of tactical environments.

Approach:
A mathematical model of team communication and coordination, predicting performance in a tactical decision-making task, will be used to drive the design of behavioral experiments that test key features of the model. Experiments will explore the impact on team performance of task complexity, of the kinds of information that can be exchanged among decision-makers, of time and workload stress, of the allocation of tasks between humans and computers and of the use of decision aids.

Progress:
Model-based experiments are planned to investigate cognitive workload limitations and biases that affect team decision making. An initial experiment will test hypotheses about the observed tendency of a team member to undervalue the judgments of others in high-workload conditions.

TITLE: Hierarchical Group Decision Making: A Multidisciplinary Approach

PRINCIPAL INVESTIGATOR: Alan M. Lesgold
University of Pittsburgh
Learning Research and Development Center
(412) 624-7045

R&T PROJECT CODE: uri5205-9002 CONTRACT NO: N0001490J1664

Objective:
The objective is to determine how the process and outcome of group decision-making are affected by members' task-relevant experience as both individuals and team members and by the availability and clarity of task-relevant information.

Approach:
Experiments will be conducted in which groups work together for extended periods of time in performing a demanding simulated air-traffic control and intruder detection task, accessing information and communicating with each other via networked computer workstations. Type of hierarchical organization and personnel turnover will be experimentally varied. Detailed records of interaction will be collected and analyzed. Parallel computer simulations will both model this behavior and explore a wider range of variables and levels of each variable than is feasible in the experimental laboratory.

Progress:
The group decision laboratory has been established and the subject workstations networked. A text-display mode for the task is functioning satisfactorily and a graphic display mode is expected to be operational soon. The network package for group experimentation runs on Novell networks with central data logging into a Btrieve database. Work has begun on an expert system that will automatically configure flight paths of intruder aircraft, but initial experimental studies will begin soon without use of that facility. The first experiment will explore the effect of team turnover; the second will test predictions of Carley's simulation re the superiority of certain command structures.

Report:
Carley, K. (1991) Coordination for effective performance during crises when training matters. Technical Report, Dept. of Social and Decision Sciences, Carnegie-Mellon University.

TITLE: Studies of Crew Coordination and Performance in Hierarchical Team Decision Making

PRINCIPAL INVESTIGATOR: Ben B. Morgan
University of Central Florida
Department of Psychology
(407) 823-5075

R&T PROJECT CODE: uri5203-9002 CONTRACT NO: N0001490J1846

Objective:
The objective of this project is determine what types of organizational structures in hierarchical teams, and what detailed behaviors of team members serve to promote coordination and team effectiveness in such complex and demanding team tasks as tactical decision making.

Approach:
Behavioral experiments will be conducted in which hierarchically organized teams carry out synthetic team tasks designed as analogs to the requirements of real Navy jobs, as determined by task analyses. Multi-platform tactical decision-making will be among the tasks simulated. Detailed recordings of communications and other behavior will be made and analyzed. Type of hierarchical structure and workload stress will be experimentally varied.

Progress:
A team performance task has been designed, programmed and refined. Pilot studies have been conducted with 5-person teams and the software fine-tuned to manipulate workload within a meaningful range.

TITLE: Information Flow and Decision Making in Teams Under Threat

PRINCIPAL INVESTIGATOR: Garold L. Stasser
Miami University
Department of Psychology
(513) 529-2415

R&T PROJECT CODE: uri5204-9002 CONTRACT NO: N0001490J1790

Objective:
The objective is to determine how types of team organization and communications affect team performance effectiveness in a tactical decision making situation, to identify communication strategies that are associated with effective performance, and to determine whether those strategies can be trained to good effect.

Approach:
Seven person teams will be engaged in an uncertain tactical decision making task comparable to the Vincennes incident. Recording and mathematical and computer simulation modeling of information transmission, dispersion and redundancy will be done. Based on a decision theoretic analysis of the task, a measure of sensitivity will be computed to index the degree to which the team's actions reflect the implications of the available information. The impact of variations in permitted communications links will be explored. Using data from both records of communications and self reports, communication strategies associated with effective performance will be identified. Experiments in which those strategies are trained will be conducted.

Progress:
The laboratory in which the work will be conducted has been established and the computer workstations networked. A copy of the MSU task program has been obtained and will serve as the starting point for programming this project's decision-making task, thus establishing a close linkage between the two projects. The first empirical experiment is planned for the Spring semester. Progress has been made in the development of a simulation of group decision making, and a collaborative relationship with Carley, who is doing simulation studies in conjunction with the Pittsburgh project, has been initiated.

STRESS AND PERFORMANCE

TITLE: Improving Problem-solving and Decision-making Skills Under Stress: Prediction and Training

PRINCIPAL INVESTIGATOR: Phillip L. Ackerman
University of Minnesota
Department of Psychology
(612) 625-9812

R&T PROJECT CODE: 4421575 CONTRACT NO:

Objective:
The proposed experiments will use stress reactivity and cognitive and perceptual abilities to predict performance under stress on a Navy-relevant analogue to the combat information center (CIC) environment. The effects of training on decision-making under stress will be evaluated with respect to the allocation of limited cognitive and perceptual resources during periods of high situational demand.

Approach:
Measures of stress reactivity and cognitive and perceptual-motor performance abilities will be correlated with performance on a single-operator analogue to the Decision-making Evaluation Facility for Tactical Teams (DEFTT) and compared to global measures of performance existing in the military record, e.g., overall job performance, the ASVAB, attrition, promotions, disciplinary actions, etc. Attentional processes in decision-making strategies will be assessed by self-report and used to develop training interventions to counter the effects of stress on performance.

Progress:
This grant is new in FY91.

Outside Funding:
Funds for this project are provided by ONT Code 222.

TITLE: Behavioral and Pharmacological Analysis of the Inverted-U Relationship Between Corticosterone and Hippocampal Function

PRINCIPAL INVESTIGATOR: David M. Diamond
University of Colorado
Health Sciences Center
Department of Pharmacology
(303) 399-8020

R&T PROJECT CODE: 4421572 CONTRACT NO: N0001491J1753

Objective:
The proposed research will identify the neuropharmacological mechanisms underlying stress-induced changes in synaptic plasticity in the rat hippocampus and investigate putative behavioral correlates through the study of hippocampal-mediated memory processes.

Approach:
Neurophysiological, neuropharmacological and behavioral studies of the awake rat will relate experimentally-induced changes in serum corticosterone levels and synaptic plasticity to changes in memory performance. Corticosterone levels will be manipulated by novel environments, chronic infusion of a corticosterone inhibitor, or by adrenalectomy, subcutaneous corticosterone pellets and receptor ligands. Memory will be tested with an 8-arm radial maze task.

Progress:
This grant is new in FY91.

TITLE: Stress Effects on Corticosterone, Cognitive Performance and Hippocampal Plasticity

PRINCIPAL INVESTIGATOR: Howard B. Eichenbaum
University of North Carolina at Chapel Hill
Department of Psychology
(919) 962-2053

R&T PROJECT CODE: 442j150 CONTRACT NO:

Objective:
The PI will assess the effects of moderate transient stressors (i.e. restraint, environmental novelty) or direct pharmacological manipulation of plasma corticosterone levels, hippocampal-dependent learning, and learning-induced enhancements of hippocampal synaptic efficacy. A second objective is an examination of the behavioral effects of the above-mentioned manipulations using olfactory paradigms known to engage hippocampal function.

Approach:
Recent advances in neuroscience indicate that the rodent olfactory-hippocampal system provides an ideal domain in which to investigate the neurobiological bases of mammalian cognitive performance in general and the effects of transient stressors in particular.

Progress:
This grant is new in FY91.

TITLE: Stress and Performance Workshop

PRINCIPAL INVESTIGATOR: Seymour Levine
Leland Stanford Junior University
Department of Psychiatry
(415) 723-2883

R&T PROJECT CODE: 4428025 CONTRACT NO: N0001491J1147

Objective:
The objectives of the meeting are: to develop new ideas and approaches that have an impact of the effects of stress on human performance; to identify individual physiological and psychological characteristics that will predict performance under stress; to develop interdisciplinary collaborations on the study of stress; to provide a tutorial for ONR staff to help define future program goals.

Approach:
A two-day workshop will be conducted for a small group of scientists from diverse fields organized into two general sessions on the physiology and psychology of stress followed by two sessions on specific issues. During each session, an overview presentation will be followed by general discussion led by a panel of five specialists.

TITLE: Development and Enhancement of a Model of Performance and Decision Making Under Stress in a Real-Life Setting

PRINCIPAL INVESTIGATOR: Colin F. MacKenzie
University of Maryland at Baltimore
Department of Anesthesiology
(301) 328-3418

R&T PROJECT CODE: 4422568 CONTRACT NO: N0001491J1540

Objective:
The objective is to produce a process model of medical decision-making in a real-life stressful medical task environment of trauma patient resuscitation and anesthesia. The effects of various stress factors such as fatigue and patient workload upon the quality of decision performance will be determined.

Approach:
Model building will begin with considerations derived from task analyses and decision trees based on expert judgment of ideal decision performance. The model will be evaluated, refined and modified based on the analysis of performance data obtained from the analysis of videotapes of actual trauma patient resuscitation and anaesthesia. The VideoNoter system for videotape analysis will be used. Stressors in the task environment will be identified and their effect on team and individual performance will be measured. The effects of fatigue, mental workload, and team interaction in sharing and shedding tasks, and the effect of physicians' experience will be investigated.

Progress:
This grant is new in FY91.

TITLE: Construction of Tests Sensitive to Dysfunction of Human Hippocampus

PRINCIPAL INVESTIGATOR: Larry R. Squire
Veterans Affairs Medical Center
Department of Psychiatry
(619) 552-8585

R&T PROJECT CODE: 4421574 CONTRACT NO: N0001491J1759

Objective:
The objective is to measure the effects of stress and individual differences in stress reactivity on hippocampal-mediated memory by constructing and administering a battery of cognitive tests to Navy recruits during basic training.

Approach:
Navy recruits will be tested with a variety of cognitive measures during relatively stressful and non-stressful periods of basic training. Patterns of test results will be compared to individual differences in stress reactivity as measured by hormonal and personality assessments in order to test the predictive validity of such measurements on performance under stress.

Progress:
This grant is new in FY91.

TITLE: Stress Reactivity: A Psychobiological Typology of Performance-Relevant Individual Differences

PRINCIPAL INVESTIGATOR: Ross R. Vickers
Naval Health Research Center
(619) 553-8454

R&T PROJECT CODE: 4421565 CONTRACT NO: N0001491WR24030

Objective:
The objectives of the proposed research are: 1) to determine whether dichotomous typologies or dimensional classification schemes are appropriate theoretical approaches to describe individual differences in stress reactivity; and 2) to use behavioral and/or physiological markers to predict the performance of individuals under stressful or non-stressful conditions.

Approach:
During the initial phase, self-report behavioral measures and hormonal markers for hypothalamic-pituitary-adrenal/gonadal activity will be used to define individual differences in stress reactivity. Later phases of study will evaluate the predictive validity of these classifications on job performance and perceptual and cognitive test performance during and after basic training.

Progress:
This grant is new in FY91.

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